GEOLOGICAL AND NATURAL HISTORY SURVEY OF CANADA
ALFRED R. C. SELWYN, LL.D., F.R.S., F.G.S., DIRECTOR.

PRELIMINARY REPORT

ON THE

PHYSICAL AND GEOLOGICAL FEATURES

OF THAT PORTION OF

THE ROCKY MOUNTAINS,

BETWEEN LATITUDES 49° AND 51° 30′.

BY

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1886.

To Alfr

Sir,—I
Mountain
the head-

Ottawa,

To Alfred R. C. Selwyn, LL.D., F.R.S.,

Director of the Geological and Natural History Survey of Canada.

Sir,—I beg to submit herewith a report on a portion of the Rocky Mountains extending from the International Boundary northward to the head-waters of the Red Deer River.

I have the honour to be,

Sir,

Your obedient servant,

Ottawa, July, 1886. GEORGE M. DAWSON.

NOTE.—Where not otherwise stated, the bearings throughout this report are with reference to the true meridian.

With the exception of the heights of stations on the railway line, the elevations given are based on barometric determinations, checked by comparison with barometric records at Calgary, Benton and Spokan Falls.

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Area embraced

This report is intended as a preliminary geological and general account of that portion of the Rocky Mountain range included between the 49th parallel on the south and the upper waters of the Red Deer River, (about latitude 51° 30′,) to the north. The Rocky Mountain Range proper, in this region, is definitely limited to the south-west by the great Columbia-Kootanie Valley, which separates it from the Selkirk and Purcell ranges, while to the north-east, the edge of the Palæozoic rocks may be regarded as its boundary. The width of the range, thus naturally outlined, is about fifty miles. The length of the portion of the range here treated of in a north-west and south-east bearing is about two hundred miles, while the approximate total area covered by this report and the accompanying map is about ten thousand square miles.

River systems draining the area.

The summit of the Rocky Mountains here constitutes the line of watershed between the Columbia and its tributaries, and the South Saskatchewan, the former flowing to the Pacific, the latter eventually reaching Hudson Bay. This report includes, on the north-east slope of the range, almost all the sources of the tributaries of the last-mentioned river. These, in order from north to south, may be enumerated as follows:—The Red Deer; the Bow, with its tributaries, the Kananaskis, Elbow, Highwood and Sheep; the North, Middle and South Forks of the Old Man, with Mill Creek, Pincher Creek and the

Waterton River. The Kootanie and Columbia rivers, flowing in opposite directions along the south-west side of the range, are fed by numerous rapid streams, the courses of most of which are comparatively short. The Kicking Horse River is the only notable affluent of the Columbia in this district. Of the rivers joining the Kootanie on the east, Wild Horse Creek, the Bull, Elk and Tobacco Rivers are the most important. The Flat-head River, which drains the central part of the range near the 49th parallel, flows southward, but eventually also joins the Kootanie.

Order observed in report.

The method followed in the arrangement of the matter in this report is as follows:—

A brief account is first given of previous geographical and geological explorations in the part of the Rocky Mountains to which it relates, with other particulars of an historical character for the district. A general description of the physical features and the bearing on these of some points of the geological structure follows, together with notes on the climatic features and general character of the vegetation. To this succeeds a description, in such detail as is deemed essential, of the various routes followed and surveyed, with which are incorporated the geological observations made on these routes. This portion of the report naturally resolves itself into a descriptive account of a number of passes which afford routes across the mountains and of the geological sections met with on these, together with similar details respecting a number of trails and valleys connecting these passes or lying between them. The routes followed during the exploration were selected either as those most easy of travel, or as those likely to afford important information as to the character of the country. Though considerable intermediate tracts remain as yet unexamined, they are, as a rule, those less likely to be entered by travellers or prospectors, being comparatively difficult to penetrate, owing to the dense character of the forest growth or to other circumstances.

The system adopted, of incorporating the geological observations with the general description of routes, is not one in general to be commended, but is justified in this instance by the purely reconnaisance character of the work reported on, and by the convenience of reference to the main facts of whatever class met with in each part of the district, which are thus together embodied in a given part of the report. These general descriptions are, however, supplemented in a subsequent chapter by a systematic, synoptical description of the geological features, to which are appended details of the useful minerals afforded by the district or known to occur in it.

Geographical Exploration and Data for Map.

Previous to the preparation of the accompanying map, the only original map giving with approximate accuracy the general features of the district has been that published in connection with Captain Palliser's report.* This is based on track-surveys made in part by Captain Palliser himself, in part by Captain Blackiston, but chiefly by Dr. Hector, who acted as geologist to the expedition under Captain Palliser. The representation of this part of the mountains on general maps of British Columbia and the North-west Territory are substantially copies, more or less accurate, of Palliser's map, the changes introduced from time to time being seldom in the direction of greater accuracy. The time spent by Captain Palliser and the members of his expedition in this particular district was, however, necessarily very limited, its examination being a portion only of a much more extended exploration; and the scale of his published map is too small for the representation of any but the more important features in a generalized manner. No portion of the geographical outlines of Palliser's map (with the exception of the western part of the Kananaskis Pass) has, therefore, been incorporated in that accompanying this report, though care has been taken to retain the names then adopted for peaks, rivers and mountain ranges.

Previous maps. Palliser's map.

The joint maps of the North American Boundary Commission, 1858–1862† represent a belt of about ten miles near the 49th parallel, (which constitutes the International boundary), in considerable detail, on a scale of $\frac{1}{63360}$. While, however, the main lines shown on these were instrumentally surveyed with sufficient accuracy, much of the topography is represented in a very unsatisfactory manner, and where checked by myself, has been found in many places to be largely hypothetical. The Boundary Commission of 1872–1874, working eastward, defined the 49th parallel up to the point on the main watershed at which the work of that above alluded to stopped. The joint maps subsequently published‡ overlap those of the first commission by about ten miles and represent a belt of country of similar width, the topographical features being given with general accuracy. While, therefore, these maps have been used as a basis for the representation of the part of the district to which they apply, the topography has been improved wherever our examinations rendered this possible. On the north-east, some of the lately run lines of the

Boundary Commission maps.

* Index and Maps to Captain Palliser's Reports. London, Government, 1865.

† Detailed maps of the North-West Boundary between United States and British possessions.

‡ Joint maps of the Northern Boundary of the United States. Washington, Government, 1868.

Dominion Land Surveys.

Dominion Land Survey reach the base of the mountains proper, and serve to fix certain points with accuracy. The line of the Canadian Pacific railway, following the Bow and Kicking Horse rivers, is also the result of instrumental survey, to which much has been added by lines run (in 1884) by Mr. T. Fawcett, D.L.S., up the Bow Valley to the head-waters of the river. Connecting with these are some local surveys made for the purpose of defining timber limits on the Kananaskis and Spray rivers.

Information incorporated in present map.

With the exception of the lines above detailed, no instrumental surveys are available for the district, and besides what appears on the Boundary Commission maps, little attempt has been made to indicate the topography on these lines in any systematic manner. In conducting the geological examination of the region, it has, therefore, been necessary throughout, to maintain a system of careful track- or paced-surveys which, in constructing the map, have been tied-in with fixed points on the instrumental lines as far as these are available. The longitudes of intermediate points have been fixed as far as possible by long bearings on prominent summits, and the latitudes of about one hundred places have been determined with a good 7-inch sextant. From the proved general accuracy of these track- and paced-surveys, and their interdependence, it is believed that the outlines represented on the accompanying map will be found correct within small limits of error. The topographical detail is filled in from sketch-plans and profile sketches, and in the vicinity of the lines of travel is substantially accurate. That indicated at some distance fro travelled routes is less trustworthy, but where the mountains have not been actually sketched no attempt has been made to delineate them. While the present map must therefore be considered as merely preliminary, its publication is justified by the want of any detailed information respecting the district, which is now attracting the attention of explorers for coal, metalliferous minerals and timber.

Connection with Bow and Belly Rivers map.

In the geological map of the country in the vicinity of the Bow and Belly Rivers, published with the report of 1882–84, the mountains constituting the eastern outline of the Palæozoic rocks are indicated, together with a part of the Cretaceous basin which occurs west of the first limestone range and within the area of the mountains proper. The present map, therefore, to some extent overlaps that one.

Surveys.

The writer first visited the region here reported on in 1874, as geologist to the second of the above-mentioned Boundary Commissions, but his observations were at that time confined to the immediate vicinity of the eastern half of the South Kootanie Pass. In 1881 he re-examined the same portion of this pass, and explored the eastern slope of the Crow Nest Pass, and the upper part of the Bow River nearly to

the position now occupied by Canmore station. In 1883, about twelve weeks were spent in this part of the mountains, and in 1884 the greater part of the working season, or about seventeen weeks, were devoted to the region. In 1883 he was assisted by Mr. J. B. Tyrrell, B.A., and in the ensuing year by Mr. James White, C.E., both these gentlemen being chiefly occupied with geographical and topographical work.

Knowledge of region in 1857.

Though this portion of the Rocky Mountains had been traversed by Howse in 1810, who followed, (according to Dr. Hector,) the North Saskatchewan and Blaeberry rivers, by Sir George Simpson in 1841, (as elsewhere more fully noted), by James Sinclair, and by at least two parties of 'emigrants' in 1841 and 1854,* no authentic information for any passes south of the Athabasca Pass was available at the time of the inception of Palliser's expedition in 1857. The Athabasca Pass, north of the region embraced by the present report, had long been employed as a route of trade by the Hudson Bay Company. It was traversed in 1810 by the geographer, David Thompson, and was followed by the botanist, Douglas, in 1827.

Sir George Simpson's narrative.

So far as I am aware, the first published account of travel in this part of the mountains is that contained in the narrative of Sir George Simpson's journey. He crossed this portion of the range on his way to the Pacific coast in August 1841, but his narrative did not appear till 1847.† His description is very indefinite, so much so, that without actual local knowledge of the region it is impossible to identify his route. Having, however, satisfied myself on this point, it may be of interest to place the result on record, as his journey dates back about to the pre-historic epoch for this region. After travelling south from Edmonton he entered the mountains by the Devil's Gap, north of the Bow River (as surmised by Dr. Hector) and passed along Devil's Lake, which he says he named 'Peechee Lake,'‡ after his half-breed guide, whose usual hunting ground was in its vicinity. Peechee, though a half-breed, was at that time a chief among the Rocky Mountain Crees. Simpson then crossed Cascade River and Forty-mile Creek (mentioning the mountain now called Cascade Mountain) and travelled, I believe, up the Bow Valley to Hole-in-the-wall Mountain, to which his remarks on p. 119 (Vol. I.) refer. He crossed the watershed range by the pass designated by his name on the map, as rendered evident by the time (seven hours) occupied in travelling from the Bow River Crossing to the summit. Had he gone by the

His route.

* See Blackiston's report in Further Papers, etc., p. 66 and Sir G. Simpson's Narrative.

† Narrative of an Overland Journey Round the World. London, 1847.

‡ This name has never, I believe, appeared on any map, or obtained any currency. The lake is now so well known as Devil's Lake that I have not endeavoured to revert to Sir G. Simpson's name, but have attached the name of Peechee to a high mountain to the south of the lake.

White Man's Pass the travelling time would have been much greater, by the Vermilion Pass much less than that specified. The White Man's Pass was, however, probably that taken by the party of 'emigrants' to which he refers as having crossed in the same year (p. 126); the emigrants being guided by an Indian known as Bras Croche.

Simpson then followed down the Kootanie Valley for some miles, and crossed to the Columbia Valley by the Sinclair Pass. He describes the wild gorge on the west end of that pass and refers to the 'Red Rock,' a conspicuous feature there. Near the mouth of this pass he met a half-breed named Berland, sent with horses for him from Ft. Colville. He visited the hot springs near the lower end of the Upper Columbia Lake (p. 128). From the Columbia-Kootanie Valley he struck across south-westward to Colville by the Grand Quête River and lakes—the Choe-coos River of Palliser and Moyie of later maps.

Routes examined by Palliser's expedition in 1858

The routes of Captain Palliser and members of his party in this part of the mountains were as follows,—In August and September, 1858, Captain Palliser traversed the Kananaskis Pass westward, followed the Kootanie Valley southward on the west side of the range, and returned to the east side by the North Kootanie Pass. Captain Palliser notes that he had been informed of the existence and situation of the Kananaskis Pass by a half-breed named James Sinclair, in 1848, when in the western Indian country of the United States.

In the same year, Dr. Hector entered the mountains by the Bow Valley, crossed the watershed by the Vermilion Pass, followed down the Vermilion River and up the Kootanie to its source, down the Beaver-foot, and back over the watershed range by the Kicking Horse Pass, now adopted for the railway. He then followed the Bow River to its source, and the Little Fork and North Saskatchewan rivers out to the eastern foot-hills.

Captain Blackiston, during the same summer, traversed the North Kootanie Pass westward, returning eastward by the South Kootanie or Boundary Pass, and rejoining the expedition at the winter quarters at Fort Edmonton.*

Routes followed in 1859

In the summer of 1859, Dr. Hector again entered the mountains by the Bow Valley, and crossed from it northward by the Pipe-stone Pass to the North Saskatchewan. He then followed the latter up and reached the Columbia by the Howse Pass, and finding it impossible to proceed further west or north-west, travelled southward by the Columbia-Kootanie Valley to beyond the 49th parallel. Captain Palliser,

* Further Papers relative to the Exploration by the Expedition under Captain Palliser, etc. London, Government, 1860.

during the same season, again crossed the mountains by the North Kootanie Pass on his way westward to the Pacific coast.

Origin of names.

Within the limits of the region embraced by the present report, a few features, such as the larger rivers, had appeared by name on maps previous to the date of the expedition under Captain Palliser. Other names introduced on the map resulting from that expedition, were those locally in use by half-breeds or Indians, or translations of these, but a considerable number of names were also given by the members of the expedition. It has not always been easy to identify the features to which some of these names were intended to apply, particularly in the case of mountains, which—owing to its small scale—are shown in a very generalized way on Palliser's map, and do not always correspond with the description of their position given in the text. In placing the names on the accompanying map, I have carefully compared Palliser's reports and map in the light of my own knowledge of the localities, with the purpose of doing full justice to the work of the expedition. While doing so I have drawn out the subjoined list of places named by the several members of Palliser's expedition, which may be useful for reference.—

Identification.

Names given by Capt. Palliser.

Named by Captain Palliser.—Kananaskis Pass, Palliser River, Mounts Fox, Back and Sabine, and the Stanford, Hughes and Macdonald Ranges. Windigo Mountain and Deception Mountain cannot be identified. The name Dunraven Range was applied to an irregular region of hills and plateaus which cannot be individualized, and is consequently omitted.

By Dr. Hector.

Named by Dr. Hector.—Cascade Mountain, Mount Rundle (after the missionary of the same name), Mount Ball (after the Under Secretary of State for Colonies in 1857), Mount Lefroy (after General Sir H. Lefroy), Brisco Range (after Capt. Brisco, of the 11th Hussars, a fellow traveller); Mounts Hunter, Goodsir, Balfour, Murchison, Forbes, Lyell, Richardson and Molar; Sullivan's Peak, (after a member of the expedition), Castle Mountain (N), on the Bow Valley; Terrace Mountain, Saw-back and Mitchell Ranges, (the latter after a travelling companion of Capt. Brisco,) Kicking Horse River and Pass, Blaeberry River, Howse Pass and Simpson Pass. A few of these localities lie beyond the northern limit of my map.

By Capt. Blackiston.

Named by Captain Blackiston.—Gould's Dome (doubtfully identified, but retained), Livingstone Range, Castle Mountain (S), North and South Bluffs on the Wigwam River, The Steeples, Galton Range. 'The Family' and 'The Pyramid' mountains, seen from the foot-hills south of the Kananaskis River, cannot be identified.

Named by Mr. Bourgeau, Botanist to the expedition.—Grotto, Pigeon and Windy Mountains and Lac des Arcs.

Other names on Palliser's map.

Mounts Yarrell and Kirby and Spence, and Waterton Lake, are on Blackiston's route, and appear on his and on Palliser's map. The last-mentioned name was, with little doubt, given by Blackiston, as he refers to it in his report dated Fort Carleton, 1858. The two former, with Newman's Peak and Mount Wilson, were probably also given by Blackiston, though nothing is said of them.

The following names in this district appear, so far as I have been able to ascertain, for the first time on Palliser's map, but are either not mentioned in the reports, or at least no statement is made as to their origin:—Palliser Range, Goat Mountain, Mount Vaux, Fairholme Mountains, Pipe-stone Creek, Beaver-foot River, Fisher's Range, Mount Robinson, Mount Fox, Mount Back, Mount Nelson, Mount Head (doubtfully identified), Crow's Nest Mountain, and Lussier River, Skirmish River (now known as St. Mary River), Bad River (now Bull River), and Wigwam River.

Names on Boundary Commission maps.

The following are names of places which appear on the maps of the first International Boundary Commission.—A-kwote-katl-nam Lake (now Waterton Lake), Kin-nook-kleht-nan-na Creek (now Kootanie Brook), Camp Akamina, Kish-e-nehn Creek, Kintla Lakes, Kish-ne-neh-na Mountains, Boundary Mountains, Kintla Mountains, Yak-in-i-kak Creek, Wigwam River, Ak-o-no-ho Creek, Tobacco River.

Names now added.

In adding the names of places which appear for the first time on the map accompanying this report, I have endeavored, as far as possible, to ascertain and perpetuate those which have come into common use. A number of these date back only to 1881, when the railway surveys in this district were first undertaken, and others have been given since the completion of the line.

Where found necessary for descriptive purposes, I have taken the liberty of naming a number of features not previously designated.

Paucity of Indian names.

Where Indian names exist, these or their equivalents in English are employed, but it is a remarkable circumstance that the Stoney Indians attach definite names to very few of the features in the region, whether mountains or rivers. As these Indians are known to be recent immigrants, and to have occupied the district for about forty years only, the paucity of names might be supposed to be accounted for by this fact. The Stoneys, however, have since incorporated with themselves the families of Mountain Crees who formerly hunted here, and many of the names which can be ascertained are either Cree or their equivalents in Stoney. I am, therefore, led to believe that the Crees themselves had come comparatively recently into possession of the region, from which they expelled some hostile tribe, probably

Cree and Stoney Indians recent immigrants.

of the Kootanie (Kootenuha) stock. This supposition finds confirmation in the statement of the missionary, De Smet, who says that some years previous to the date at which he wrote (1849), the Crees and Assiniboines inhabiting the Athabasca region had been forced to move southward, owing to the scarcity of game, in search of buffalo. It may probably have been at about this time that the Crees pushed their way into this part of the mountains. The present tribe of Rocky Mountain Stoneys (or Assiniboines) is known to be related to the Athabasca Assiniboines. These, according to De Smet, separated from the main body of the same people to occupy the Athabasca region about sixty years before 1849, or in 1790.*

More detailed enquiry among the Kootanie people than I have been able to make, might settle the question as to their former territorial claims. It is certain, however, that tradition relates constant feuds and repeated raids across the mountains between the Kootanie and the Blackfoot tribes, and that the former have been accustomed from time immemorial to cross to the eastern plains to hunt buffalo. It is also probable from the habits of the Blackfoot people, who are essentially plain Indians, that they would not willingly inhabit for any length of time these mountain fastnesses.

Previous Geological Explorations.

Dr. Hector's reports.

The first published geological information for this part of the Rocky Mountains is that contained in Dr. Hector's reports and journals † in connection with Palliser's Expedition. The substance of the geological reports is also given in a systematic form in a paper, accompanied by a map, by Dr. Hector, in the Quarterly Journal of the Geological Society.‡

Mr. Bauerman's report.

In 1861, Mr. H. Bauerman, attached as geologist to the first of the Boundary Commission expeditions above referred to, visited and examined that part of the present district near the 49th parallel. The result of his investigations, however, remained unpublished till 1885, when it appeared in the last report of the Geological Survey (1882-84), Mr. Bauerman having kindly communicated his manuscript report for that purpose.

* Western Missions and Missionaries, Rev. P. J. De Smet, New York, 1859.

† Papers relative to the Exploration by Captain Palliser, etc. London, Government, 1859.

Journals, Detailed Reports and Observations relative to the Exploration by Captain Palliser, etc. London, Government, 1863.

‡ Vol. XVII., p. 388, see also Edinburgh New Phil. Jour., N.S., October, 1861. Having had occasion to re-examine many of Dr. Hector's routes in the North-west Territory and Rocky Mountains, the writer wishes to note the great general accuracy and value of the work done by Dr. Hector, whether geographical or geological.

Other reports and papers.

Under the title of "Physical Geography of the North-west Boundary of the United States," Mr. George Gibbs published, in 1872, in the Journal of the American Geographical Society, a paper giving an account of the orographic features of the region in the vicinity of the 49th parallel, with some notes on its geology. This paper is founded on information gained by Mr. Gibbs while connected with the United States contingent of the same Boundary Commission, to which Mr. Bauerman was attached. Mr. Meek subsequently described a few Carboniferous fossils obtained by Mr. Gibbs at Katlahwoke Creek, in the Rocky Mountains.* He states his belief that this locality is the furthest north in the range at which rocks of this age had been determined by organic remains, but in this belief he was in error, as Dr. Hector had many years previously recognized Carboniferous limestones much further north.†

In The Professional Papers of the Royal Engineers (Paper 14, Vol. III., read January 22nd, 1864,) Lieutenant Wilson, R.E., gives some account of the geography of the same region described by Mr. Gibbs, together with details as to the mode adopted in fixing the boundary line.

In 1874, the writer, as previously stated, made a geological examination of a portion of the South Kootanie Pass and its vicinity, including the valley of Akamina Brook to the boundary monument on the summit ridge. The result of this work forms Chapter III. in the Geology and Resources of the 49th parallel,‡ where a geological section of the portion of the pass examined and several sketch sections of mountains are given. The features of the region are again summarized in a sketch of the geology of British Columbia, published in the Geological Magazine,§ and in the Sketch of the Physical Geography and Geology of the Dominion of Canada.|| Preliminary notices respecting the general structure of the part of the range included in the present report also occur in the reports on the district in the vicinity of the Bow and Belly rivers.¶

Mr. H. H. Winwood, in a letter to the Geological Magazine, in 1885, announces the discovery of Cambrian fossils in the Kicking Horse Pass.**

The publications above noted are, I believe, the only ones bearing on the geology of the region previous to the report herewith presented.

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* Bulletin U. S. Geol. & Geog. Survey, Vol. II., p. 851, 1876.
† See his report and paper above cited.
‡ Montreal, 1875.
§ London, April and May, 1881.
|| Published by the Geological Survey, 1884.
¶ Reports of Progress, Geological Survey, 1880-82 and 1882-84.
** N.S. Dec. III., Vol. II., p. 240. See also 'Science,' Vol. III., p. 647.

General Orographic Features.

Interest attaching to the region.

The portion of the Rocky Mountains embraced by this report may be regarded, for several reasons, as one of particular interest and importance. It is the most northern portion of the range of which any systematic geological—or indeed geographical—exploration of a connected character has yet been made, and it differs very considerably in character from that part of the range which traverses the territory of Montana, where the mountains are comparatively diffuse and irregular in outline. The northern portion of the district is now traversed by the Canadian Pacific railway, which renders it easily accessible, and whether from the point of view of the geologist, botanist or zoologist, or regarded merely as an alpine region affording the most striking and attractive scenery and unlimited opportunities for mountain climbing and exploration, it is likely to attract in the near future many visitors. Apart from the circumstances of the discovery of various metalliferous deposits already made, the existence of extensive basins of newer rocks holding numerous seams of excellent coal gives promise of important developments in the near future.

The Cordillera belt.

The term Rocky Mountains is frequently applied in a loose way to the whole mountain region bordering the west coast of North America, which is more appropriately—in the absence of any other general name—denoted as the Cordillera belt, and includes a number of mountain systems and ranges, which on the 40th parallel have an aggregate width of about one thousand miles. Nearly coincident, however, with the latitude of the head-waters of the Missouri, a change occurs in the character of this Cordillera region; it becomes comparatively strict and narrow, and runs to the 56th parallel or beyond, with an average width of about 400 miles only. This narrower portion of the Cordillera comprises the greater part of the province of British Columbia and consists of four main ranges, or more correctly speaking, systems of mountains, each composed of a number of constituent ranges. These mountain systems are from east to west, (1) The Rocky Mountains proper; (2) Mountains which may be classed together as the Gold Ranges; (3) The system of Coast Ranges sometimes improperly regarded as a continuation of the Cascade Mountains of Oregon and Washington Territory; (4) A mountain system which in its unsubmerged parts constitutes Vancouver and the Queen Charlotte Islands. This last is here actually the bordering range of the continent, as beyond it, after a submarine plateau of inconsiderable width, the bottom shelves very rapidly down to

to the abyssal depths of the Pacific. The Tertiary coast ranges of the south are here entirely wanting. Between the second and third of the above mountain systems is the Interior Plateau of British Columbia, with an average width of about one hundred miles, a mean elevation of about 3,500 feet, and peculiar character and climate.

The Rocky Mountains.

The present report refers more particularly to a portion of the Rocky Mountains proper. This system of mountains has, between the 49th and 53rd parallels an average width of about fifty miles, which in the vicinity of the Peace River decreases to forty miles, the general altitude of the range as well as that of its supporting plateau at the same time becoming less. Beyond the Peace River region these mountains are known only in the most general and unsatisfactory way. The portion of the Rocky Mountains which has been explored is bordered to the eastward by the Great Plains, which break into a series of foot-hills along its base, and to the westward by a remarkably straight and definite valley, which is occupied by portions of the Columbia, Kootanie and other rivers, and is known to preserve its general direction and character for over six hundred miles.

Trend and width.

The general trend of that portion of the Rocky Mountains here particularly described,—between the parallels of 49° and 51° 30′—is about N.N.W.–S.S.E., but when more closely examined it is found to include three subordinate trends. That portion of the system, extending on the east side, from the 49th parallel to the South Fork of the Old Man River, has a general bearing of N. 35° W. Thence northward to the point at which the Highwood leaves the mountains, the general trend is N. 12°W., after which the bearing again becomes about N. 35° W., and so continues to the northern limit of the map. Notwithstanding the changes in general trend, the average width is preserved throughout with considerable constancy, though it becomes greater than usual in the north-and-south trending portion, where large Cretaceous infolds occur, as elsewhere more fully described. The constituent ranges and ridges conform very markedly to the varying directions above stated, and while these are most clearly shown by the outer eastern range, the three directions of trend are scarcely less evident on the western border. The least regular and most tumultuous portion of these mountains is that in the neighborhood of the 49th parallel.

The base-level of the Rocky Mountain range is much higher on the eastern than on the western side. On the east, as ascertained by taking the average level at which the larger streams leave the mountains proper and pass into the foot-hill region, it is about 4,360 feet. On the west, the average elevation of the Columbia-Kootanie Valley is approximately 2,450 feet. In consequence of this difference, the passes traversing the range have, (as first noted by Captain Palliser), a steep

and sudden descent to the west of the watershed in contrast to the more gradual slope to the east.

Structure and origin of the foot-hills.

The foot-hills, though they might be regarded structurally as a portion of the mountains, being composed of rocks flexed and disturbed parallel to and contemporaneously with those of the mountains proper, differ much in their general appearance and character from them, and seldom equal even their outer and lower summits in height. The amount of disturbance in the foot-hills is not less than that found in the mountains, and in many places is even greater, the beds being often vertical, or even overturned, in transverse sections several miles in length. They are, however, composed of the Cretaceous and Laramie rocks, which, further east, in nearly horizontal and unbroken sheets, form the substructure of the Great Plains; while the mountains proper are composed of the older Palæozoic rocks which never appear at the surface in the area of the plains. To the less resistence to denudation which the newer and softer rocks have offered, must be attributed the inferior present elevation of the foot-hill region, and the comparatively rounded outlines of its hills and ridges, which are almost everywhere covered with vegetation. During the time intervening between the close of the Laramie and the earliest Miocene, a truly surprising amount of denudation must have occurred, of which in this region no geological record remains.

Character of the foot-hills.

The average width of the foot-hill belt may be stated as about fifteen miles, and its eastern margin, where the sharp flexures abruptly subside, forms a line which is almost exactly parallel to the trend of the base of the mountains previously alluded to. The eastern base of the rugged and bare mountains coincides everywhere so closely with that of the Palæozoic rocks, that this geological line may be taken as defining also the boundary between the mountains proper and the foot-hills. The foot-hills region is characterized by series of long ridges, or hills arranged more or less definitely in linear series, the positions of which have been determined by the existence of zones of harder rock—generally sandstones. Between these ridges are wide valleys in which the smaller streams course, while the larger rivers, having their soures in the mountains, generally cut across nearly at right angles. Though very well marked south of the Old Man River, these ridges are there usually rather low, and the proportion of wooded country being quite small, the prairie may be said to spread up to the very base of the mountains proper. North of the North Fork of the Old Man, however, the hills and ridges grow higher and more abrupt, and the wooded areas become more considerable till, about the Highwood River and Sheep Creek, extensive forest areas, interspersed with tracts of burnt woods, render the base of the mountains well nigh inapproachable, except

Foot-hills low to the south.

Higher northward.

along the river-valleys. The greater height and roughness of the foot-hill region in the vicinity of the Highwood River, Sheep Creek and the Elbow River, is co-ordinate with an increased height of the base-level of the mountains, which here attains its maximum; the levels at which the Highwood and Elbow Rivers leave the mountains being approximately 4,780 and 4,800 feet respectively. The streams which issue from the mountains at the lowest levels are the South and Middle Forks of the Old Man and the Bow River. The two first may be considered together as occupying a structural break in the front of the range, and have a level at this point of little over 4,150 feet. The Bow River, but for its greater size and erosive power, which have enabled it to produce a great valley, would probably have at its exit from the mountains, a height as great as that of the Elbow or the Kananaskis at a corresponding point, but it actually crosses the outer range with an elevation 4,170 feet only.

Appearance of the foot-hill region.

Where the summits of the foot-hill ridges are not crested with outcropping ledges of sandstone, their outlines are generally rounded and flowing. The parallel valleys contain a deep, rich, black soil, and under the influence of a sufficiently abundant rainfall, the vegetation is wonderfully luxuriant. There are indications of a very palpable character that the southern foot-hills were at a time not very remote, much more thickly wooded than at present, and that the recurring fires have much extended the open country. Before many years have passed, the same influence will have produced great changes in the northern parts of this region, still thickly wooded, and districts now almost impenetrable from tangled forest and windfall will have become open pasture lands.

Few regions in a state of nature can compare with the southern part of the foot-hills in beauty. The long grassy slopes covered with an infinite diversity of wild flowers, the rivers fresh from their mountain sources, rapid, cold and clear, and the ever-changing views of the great background of mountains, combine to form a most attractive landscape.

Structure of the mountains.

As in most mountain regions (and here specially apparent on account of the strict parallelism of the rock-folding), the ruling feature of this part of the Rocky Mountains may be described as a system of parallel ridges, crossed nearly at right angles by a series of transverse breaks. These are abundantly evident, whatever their cause, which from a geological point of view is not very clear. On a larger scale, the plan of the foot-hills is repeated in the mountains, and some of the more evident breaks are continued quite through the foot-hills to the eastern plains, while in other parts of the foot-hills—as between the Middle and North forks of the Old Man—a series of similar

breaks is found traversing the foot-hills themselves, but not affecting the mountains. It is an interesting question, but one on which, as yet, we have scarcely sufficient evidence for decision, whether such transverse breaks are due to lines of comminuted fracture and shattering of rocks, or whether they represent portions of the older drainage-valleys of the axis of elevation, which, by drawing to themselves the waters of the smaller streams of the longitudinal valleys, have succeeded in maintaining their supremacy as drainage channels even to the present time, though the longitudinal valleys have become the most noticeable features. It appears highly probable that both causes have been concerned in their formation. Two systems of valleys.

So far no evidence of extensive faulting has been discovered in connection with these transverse lines. In no case, however, in the region now described, does such a transverse break preserve its character so definitely across the whole breadth of the range as to form a direct 'pass' or practicable route of travel, though the North Kootanie Pass closely approaches this condition. The routes offering the greatest facilities for crossing the mountains, generally follow zig-zag courses, partly along the longitudinal valleys, and seek the lowest points at which to traverse the intervening mountain ridges. In consequence of this, the lengths of the various transverse passes are often considerably greater than the actual width of the mountains. In the following list, the known passes in this part of the range are enumerated in order from south to north, with the length of each measured along the direction of the trail from the eastern to the western base of the mountains. The altitude of each, at the watershed or main summit, is given in the second column.— Routes across the mountains.

List of passes.

	Length in miles.	Elevation at watershed.
South Kootanie or Boundary Pass	66	7,100
North Kootanie Pass	48	6,750
Crow Nest Pass	56	4,830
North Fork Pass (1)	46	6,773
Kananaskis Pass	85	6,200
White Man's Pass (2)	70	6,807
Simpson Pass (3)	70	6,670
Vermilion Pass (4)	88	5,264
Kicking Horse Pass	104	5,300

(1). Measured from the Elk River Crossing in a straight line to the Kootanie Valley, the western continuation of this pass not having been explored.

(2). Measured up the Bow Valley on the east, and at the west end crossing the Brisco Range by Sinclair Pass.

(3). Measured up Bow Valley on the east, and across the Brisco Range in a direct line, by reported pass.
(4). The eastern and western ends of this pass are identical with the last.
(5). By the railway line, 111 miles.

It is probable that even within this district there are other passes across the watershed range beside those here named. The Indians, in the course of their hunting expeditions, travel on foot in every direction across the mountains, but designate as passes only the routes which are not too steep or rough for horses.

Character and importance of the passes.

Most of the passes above enumerated cross subsidiary summits of some height west of the main watershed. The South and North Kootanie Passes have long been in regular use by the Indians, and both these, after descending into the Flat-head Valley, in the centre of the mountain region, cross a second high 'divide' between this river and the Kootanie Valley. The Crow Nest Pass was little used by the Indians, owing to the thick forest prevailing along parts of it, but it was some years ago chopped out, and rough bridges were thrown over some of the streams, to provide a route for taking horses and cattle eastward across the range. The North Fork Pass appears for the first time on the accompanying map, and was not known, except by Indians, till crossed by myself in 1884. The Kananaskis Pass was traversed by Captain Palliser in 1858, and has been much used by the Indians. The White Man's Pass probably derives its name from the circumstance of its use by emigrants in 1841 (see p. 10 B). Sir George Simpson in the same year, crossed the mountains by the pass to which his name is now attached. The Vermilion Pass has long been a much-travelled Indian route, and takes its name from copious chalybeate springs which deposit large quantities of ochre. The Kicking Horse Pass was little known, and scarcely used by the Indians, probably on account of the thickness of the woods and rough character of parts of the valley for horses.

Howse and Athabasca Passes.

About fifty miles north of the last-named pass, and beyond the limits of the accompanying map, is the Howse Pass, and thence to the Athabasca Pass, a further distance of sixty-three miles, no practicable route is known across the axis of the range. In 1884 I learned from the Stoney Indians that a hunting party, having heard reports of abundance of game in the region, had during the summer tried every valley between the Athabasca and Howse passes, but had been unable to get their horses over, being repulsed either by impassable rocky mountains or by glaciers and snow-fields which filled the intervening valleys.

Constituent rocks of the mountains.

The ancient crystalline rocks form no part of this portion of the Rocky Mountains, which is chiefly composed of Cambrian, Devonian

and Carboniferous strata, violently flexed and often completely overturned. The differences in resistence to denudation of these rocks are not on the large scale considerable, and the regions of greater and less elevation thus depend closely on the nature and volume of the folds of the component strata. The most important interruption to the uniformity of this part of the range is found in the fact that the folding has in several places been so extensive as to include large areas of Lower Cretaceous rocks, which appear, previous to the main era of mountain elevation, to have overlain this region in great volume. Wherever these rocks constitute considerable areas of the present surface, we find a partial repetition of the conditions obtaining in the foot-hills, characterizing tracts which are surrounded by ranges of limestone or other Palæozoic rocks. Where such areas are extensive—as in the region between the North Kootanie Pass, the Highwood River and the Elk—the neighbouring and intervening Palæozoic ranges, are, though still very prominent, owing to a lack of support and the more rapid and uniform wearing away of the softer Cretaceous rocks, of less elevation than elsewhere, and the general height of the mountain region is inferior. Where such softer areas are wanting, as near the 49th parallel and about the head-waters of the Bow River, the general altitude is correlatively increased.

Higher and lower areas.

The culminating point of the Rocky Mountains is doubtless to be found about the 52nd parallel of north latitude, or between this and the 53rd parallel, where Mounts Brown and Murchison, occur with reputed altitudes of 16,000 and 13,500 feet respectively, and Mount Hooker, also reported to be very lofty. These heights, however, are not great in comparison with those found in some other mountain ranges, and those met with in the region here particularly described are even less. The height of the adjacent country, and the yet more considerable elevation of the drainage level within the area of the mountains, moreover, reduces the apparent magnitude of the range, and mountains rising more than 5,000 feet above the point of view are seldom encountered. The scenery is, therefore, not of the impressive magnitude of that met with in such mountains as the Himalayas, or even the higher portions of the Alps. It has, however, a character of its own, and what it may want in actual dimensions is compensated by its ruggedness and infinite variety, the mass of its broken escarpments and the height of its bare cliffs, which rise often over valleys densely filled with primeval forest. The contrast in respect to form is very marked between these mountains and those belonging to the Selkirk and Purcell ranges, on the opposite side of the great Columbia-Kootanie Valley. Along the eastern side of this valley, the outer range of the Rocky Mountain

Height and appearance of the mountains.

system forms an almost continuous wall of bare and shattered, though not very lofty, limestone peaks. The Selkirk and Purcell ranges, on the contrary, begin to assume a rugged character only in the vicinity of the axis of the mountain system, while the flanking hills, for a number of miles back from their base, show gently swelling outlines, and are, as a rule, thickly covered with forest.

Irregular mountain region.

That portion of the mountains south of the North Kootanie Pass presents but little of the structural regularity elsewhere met with, and the characteristic parallelism of features appears to be obscured by a geological uplift which brings considerable areas of Cambrian rocks to the surface in the vicinity of the South Kootanie Pass. Whether connected with this uplift, or due to other causes, the parallel folding of the rocks of the mountains, elsewhere referred to, is not here well marked, or acute, and the beds for the most part lie at remarkably low angles. The eastern base of this part of the mountains is also anomalous in character, being, between Waterton Lake and the South Fork of the Old Man, cut by a number of small but deep valleys with north-east and south-west trends, which rise some miles back from the outer edge of the range and hold the tributaries of the Waterton River and the South Fork. The block of mountains bounded by the South and North Kootanie Passes, the Flat-head Valley and the eastern foot-hills is, in fact, peculiar in that it discharges its drainage nearly equally in all directions. Castle Mountain (S), the summit of which is evidently composed of massive and nearly horizontal beds of limestone, is one of the higher and more remarkable peaks of this group of mountains. The other central mountains are not known.

Mountains between North Kootanie and Kananaskis Passes.

Beyond the North Kootanie and Crow Nest passes, the parallel mountain ridges become well defined. The Livingstone Range, continued further northward by the Highwood Range, forms the outer ridge of the mountains, and extends with slight interruption for a distance of eighty miles, to the Elbow River. A second limestone ridge is formed by the Flat-head and High Rock Ranges, which lie nearly parallel to the first, and have like it a slight convexity eastward. The Elk Mountains continue this line to the sources of the Elbow, where the space between this and the outer range having become comparatively small is nearly filled by the intercalated Misty Range. Further west, the Wī-suk-i-tshak Range forms a third imperfect parallel, and beyond is the very rough and high range to the west of the Elk River, between which and the Hughes Range, bordering the Columbia-Kootanie Valley, a wide space remains unknown.

Mountains between Kananaskis and Vermilion Passes.

The mountain region between the upper part of the Elbow River and Kananaskis Pass on the south, and the Bow River and Vermilion Pass on the north, wants the wide Cretaceous valleys found in the part last

described, and is composed of from eight to ten main ranges, with but two wide intervening valleys—one running from the head of the Kananaskis to Spray River, the other holding the head-waters of the Kootanie. The parallelism of these ranges is not less well marked, but their continuity is frequently interrupted both by transverse valleys and by an echelon-like arrangement which subsists between them. Fisher's Range here constitutes the eastern front of the mountains. Behind it a second tier is formed by a somewhat irregular range, which ends in Pigeon Mountain on the Bow. The Opal Mountains and connecting elevations ending on the Bow in Mount Rundle, form a third range, while the Kananaskis and Goat Ranges, with Terrace Mountain, constitute a fourth. The Spray and Bourgeau Mountains are the best known portions of a fifth parallel, while a sixth runs southward from Pilot Mountain, but dies out before reaching the White Man's Pass. The Blue Mountains and connected mountains ending in Mount Ball on the Vermilion Pass, form a wide and somewhat irregular seventh range. Between this and the important ridge formed by the Mitchell and Vermilion Ranges, there are probably two short intercalated ranges, of which the ends are seen on the Cross River. The Brisco and Stanford ranges constitute the western elevation of the mountains, and are wider and more persistent than most of those above named.

Mountains North of the Bow River and Vermilion Pass.

North of the Bow River and Vermilion Pass, the parallelism of the constituent ranges, so far as known, is equally great, but the names Fairholme Mountains, Palliser and Saw-back Ranges are there applied to rather extensive blocks of mountains, the constituent ridges of which have not yet been mapped. The Bow Range and Waputtehk Mountains, cut across by the Kicking Horse Pass, constitute together a a very massive range, which to the west, in the vicinity of the pass, becomes broken up into rather irregular groups of mountains. The lofty Otter-tail Mountains are continued to the north-west by two ranges, the Van Horne Mountains and Mount Hunter, while the Beaver-foot Range (really a continuation of the Brisco Range) fronts on the Columbia Valley.

Relations of higher mountain regions to watershed.

As will have been gathered from the foregoing general description, no single ridge or system of elevations constitutes the watershed range in this part of the mountains, nor does the portion of the mountains characterized by the greatest connected areas of high mountain country and crowned by most of the higher peaks, coincide with it. A line following this most elevated region would probably run from the neighbourhood of Waterton Lake west-north-west to the vicinity of the Lizard Mountains, thence northward to the west of the Elk River, to latitude 50° 30′, and thence north-westward, passing through the Blue Mountains and Bow Range. Only in the last-described portion of its length

would it be identified with the main water-parting. Therefore, other circumstances than the position of this line of greatest elevation must have operated in determining the watershed; or that which was originally the highest part of this mountain system is still marked approximately by the present position of the 'main divide,' but has since become relatively depressed by the more active progress of denudation. It is quite possible that the latter supposition is correct. The steeper pitch and consequent greater erosive power of the westward-flowing streams, with other minor circumstances not necessary here to detail, afford ground for the belief that the line of the watershed has, during the process of the denudation of these mountains, retreated eastward for a greater or less distance.

Actual position of the watershed.

From the South Kootanie summit, the actual watershed runs north-westward to the north Kootanie summit, probably forming a very sinuous line, as it does not here appear to coincide with any single range. Thence it follows the Flat-head Range for some distance, but on the Crow Nest Pass is found to lie in a comparatively low tract several miles west of that range. Thence, for many miles northward, the High Rock Range forms a definite line of water-parting. At the northern end of this range it is quite probable that the watershed lies to the east of its axis, though this point has not been determined. It next follows the Elk Mountains for a few miles, crosses the wide longitudinal valley in which the Kananaskis and Elk head in a common, swampy tract, and after following the southern continuation of the Spray Mountains round the head of the Upper Kananaskis Lake, falls back on the White Man's Pass to the next range to the west. Thence, after following the Blue Mountain Range, it is found to the east of the main axis of elevation on Simpson Pass, after which it becomes identified with this axis in the Bow Range and Waputtehk Mountains. Regarded as the eastern boundary of the province of British Columbia, it presents on the map an undesirable sinuosity, but possesses a practical advantage in being always easily determined on the ground in each particular locality, and requiring no elaborate survey of system or land-marks to fix its position.

Most lofty mountains.

In the region embraced by the map, Mount Lefroy (of Hector), with an altitude of 11,658 feet above the sea, appears as the highest peak. It is the most lofty of which any actual measurement has been made, but others may still be found with an equal or greater height. It is quite probable that the blunt summit a few miles north-west of Mount Lefroy, in the same range, and forming the centre to which the spurs seen on the south side of Kicking Horse Pass attach, is higher. The remarkable peak called Assiniboine Mountain, of which I estimated the height, as seen from a considerable distance, at 11,500

feet, may also prove to exceed Mount Lefroy when it shall be measured, and there are some very lofty mountains in the unexplored tract west of the Elk River, which have been seen only from high points east of the Elk many miles distant.

A number of mountains shown on the map are known, however, to exceed 10,000 feet in height, while whole ranges and groups of peaks in the district surpass 8,000 feet.

Escarpment-like mountains.

The type of mountain structure most extensively developed in this region is that of the escarpment, with cliffs or very steep slopes on one side, and long and comparatively light slopes on the other. The steeper slopes generally face eastward, in consequence of the prevalence of westward dips, though the conditions are reversed on the west side of the range. The ridges are very often composed of massive beds of limestone, and these lighter slopes are at an angle sometimes identical with the dip of the beds; in which case inclined surfaces of rock, almost as bare as the more abrupt, eastward-facing cliffs, are often formed. Among the more striking instances of this type of mountains may be mentioned, Prow Mountain, on the Red Deer, Mount Rundle and the range running south from it, and others in this vicinity, also part of the Highwood Range south of Mount Head. Mountains of this form are, however, numerous everywhere in this district. Where the mountain tops are formed of nearly horizontal beds of the massive limestones, as not infrequently happens, the easy disintegration of these rocks along jointage-planes, at right angles to the bedding, produces summits with very striking forms, of which the upper parts are almost sheer cliffs, often of very great height. The conspicuous, block-like summit of Chief Mountain is a good instance of this type, others are the Crow's Nest and Bee-hive Mountain, with summits resembling broken columns, and Castle Mountain, on the Bow River, with its long ranges of vertical, rampart-like cliffs. A later stage in decay of mountains of this type produces chimney- or spire-like peaks, such as are found running north from the Crow's Nest, at the eastern extremity of Castle Mountain (N), and in a very picturesque peak at the head of the short valley which joins the North-west Branch of the Old Man River near its head at the fall. The index-like pinnacle, at one end of Castle Mountain, of the southern part of the range, is another instance. When the limestone series has been turned completely on edge, as in the western ridge of the Saw-back Range, in the Opal Mountains and elsewhere, the limestones entirely lose their characteristic massive appearance and produce ranges with a very straight crest, but narrow, and with saw-like outlines.

Block-like mountains.

Serrated ranges.

The rocks of the underlying quartzite series, though in themselves hard, are not in such thick beds as the limestones, and are, moreover,

Quartzite and slate mountains

very much shattered by innumerable jointage-planes. As a consequence of these conditions, the forms of the mountains composed of them are not so striking nor so much individualized. They tend to form systems of angular, steep-sided ridges, separated by V-shaped valleys, which radiate in all directions from the higher parts. If of inferior height, or when erosion has not proceeded so actively, they may become almost rounded in outline. The slate mountains on the Bow River, and the Van Horne Mountains on the Kicking Horse, may be mentioned as illustrations of these.

Unexplored region.

The largest part of that portion of the Rocky Mountains represented on the accompanying map which yet remains completely unexplored, is that alluded to as lying between the Elk River and the Kootanie. This region is known to be one of great difficulty, not only from its rugged, mountainous character, but from the fact that owing to its abundant rainfall, the forest growth is there particularly impenetrable. Judging from our experience elsewhere, however, I believe it would not on actual trial prove nearly so difficult as reported. It was not entered by us, merely because the time at our disposal was not more than sufficient for traversing the main routes, and for the delimitation of the more important Cretaceous areas in the region. The cause of its being avoided by the main trails is probably to be found chiefly in the position of the Elk River, which constitutes at all but its lowest stages, a well-nigh impassible barrier, being as a rule too deep to ford with animals, and too swift for rafting. In view of the gold-bearing character of Wild Horse Creek and the Bull River, both heading in this unexplored tract, it would appear to be one worthy of the attention of the prospector.

Normal conditions of drainage.

The transverse valleys, previously described as constituting one of the well-marked structural features of this part of the Rocky Mountains, are so numerous, that it would appear to be the normal condition for each of these to unwater a comparatively limited tract of the mountains, receiving as tributaries the streams from the longitudinal valleys. To such an arrangement the valleys of the several branches of the Old Man, together with those of the Highwood, Sheep, Red Deer, and several others, conform pretty evidently. In other cases, however, owing probably to causes explicable on grounds of geological structure, the longitudinal valleys have become the main water-ways, and collect the streams of a number of areas which drain toward them through smaller transverse breaks. Of this, the Elk River is the most remarkable example, and the determining cause in this case is evidently to be found in the existence of the long infold of the softer Cretaceous rocks which it follows. The upper part of the Kootanie River is another case in point, but the importance of the valley is there due to the existence of an anticlinal axis of Cambrian rocks, which is continued northward

Longitudinal intercepting streams.

in the Beaver-foot Valley. Both these streams eventually break across the intervening ranges to the west. The Flat-head Valley is another instance of the same kind, but the cause of its existence is not so obvious. It is worthy of note that all these large, intercepting, longitudinal streams flow southward.

The Bow Valley

The course of the Bow River in the mountains, is very remarkable. After first flowing in an anticlinal Cambrian valley, it turns eastward and breaks completely across the series of mountain-ridges which form the Saw-back Range. It then reaches an important Cretaceous infold, and after following it for a number of miles to the south-east, again turns nearly at right angles, and breaking through the outer ranges, reaches the foot-hills. It is highly probable that the Bow at one time flowed through the valley now occupied by Devil's Lake, the singular characters of which are elsewhere described, and that the change in its course took place either during or subsequently to the glacial period. Such a change might have happened in consequence of the more prolonged blocking of the Devil's Lake valley by glacier ice derived from the high mountains surrounding it. The only other instance which need be referred to of a now disused channel, which evidently at a former period carried a large stream, is that of the valley which opens at each end on the Spray River and runs to the east of the Goat Range.

Abandoned river-valleys.

Antiquity of the drainage system.

In so mountainous a region, such changes must necessarily be quite exceptional, as drainage channels once established would in general be very persistent. Evidence of the great antiquity and permanence of the channels of drainage is abundant. Except it were the complete blocking of valleys by masses of glacier ice, circumstances under which the larger streams would be diverted from the depressions they have now produced, are well nigh inconceivable, and most of the rivers appear to have simply re-occupied these old courses after the ice of the glacial period had passed away. The transverse valleys are supposed to be, geologically, the most ancient, as they are those for which least apparent determining cause can be found at the present day. A circumstance indicating their vast antiquity, is that the lowest summits between the tributaries of contiguous transverse valleys, are in several cases as high as, or higher, than those of the main watershed of the mountains in the same neighbourhood. A marked superiority once obtained by any of the larger streams is of course likely to be perpetuated and to increase at an accelerated ratio in consequence of the greater erosive power thus gained. The formation of such main water-courses as the Bow, Elk, etc., is probably due to such cumulative increase.

Lakes.

The lakes found in or adjacent to this part of the mountains are not very numerous or important. The largest are the Columbia Lakes, the

character and origin of which are elsewhere spoken of. The upper lake is nine, the lower about eight miles in length, the width of each being in some places about a mile. Devil's Lake, ten miles in length, but narrow, has been referred to as probably occupying part of a former river valley. Trout Lake on the White Man's Pass is of the same character, but much smaller. The upper and larger of the Waterton Lakes, nine miles long, is pretty certainly held in by the accumulation of debris brought down by the Kootanie Brook, though perhaps also in part dammed by moraine material. In any case it certainly occupies the position once held by a glacier in the same valley. The lower Waterton Lake is probably also moraine-dammed. Bow Lake doubtless occupies the bed of a former extension of the glacier still existing at its head. Several smaller lakes such as that on the summit of the Vermilion Pass have evidently been produced by debris from tributary streams or torrents blocking up the valleys. Kicking Horse Lake flows westward over a lip of rock. It occupies part of the bottom of a wide valley transverse to the watershed range, which probably drained eastward before it became filled by glacial drift deposits in the vicinity of Stephen station. There are also a number of small lakes and pools which lie in cirques or occupy the upper ends of deep valleys heading in the mountains, and some of these may rest in true rock-basins of glacial origin.

Columbia-Kootanie Valley.

The Columbia-Kootanie Valley, bordering the Rocky Mountains on the west, has already been referred to as an orographic feature of the first importance. The portion of this valley included in the present report and map extends from the 49th parallel to the mouth of the Kicking Horse, with a length of one hundred and eighty-five miles. The eastern side of the valley is here formed by the escarpment-like western range of the Rocky Mountains, while the slopes on its western side are, as has already been stated, longer and lighter. The general direction of dip of the rocks of the first-mentioned range being eastward, this great valley may be considered as an exaggerated instance of the strike valleys elsewhere met with in this region. Indications are not wanting of fracture and disturbance in the rocks along the line of the valley, but it appears probable that it has been produced for the most part by the normal action of streams cutting along the basset-edges of the strata, and that as it has increased in depth, it has also changed its position laterally, moving to the eastward.

Its present anomalous character.

Active erosion is, however, not now in progress in this great valley. Like most of the larger valleys, it is evidently of pre-glacial origin, and is deeply filled with drift materials. We cannot even certainly tell in which direction it discharged in pre-glacial times, though it was probably southward. The present condition of the valley

in regard to its drainage is both peculiar and anomalous. The Columbia River, finding its furthest source in the Upper Columbia Lake, flows thence through the second or lower lake northward for about one hundred and seventy miles to its great bend at the mouth of the Canoe River, while the Kootanie River enters the same wide longitudinal valley nearly abreast of the head of the Upper Columbia Lake, and flowing southward, eventually joins the Columbia at a much lower point. The Kootanie, where it enters this great valley through a gorge in the western range of the Rocky Mountains, is already a large stream, which can be forded at low water only. It is very rapid, and its whole course as far as and beyond the 49th parallel is swift and interrupted by numerous rapids or 'riffles.' The Columbia, owing to the considerable number of streams and springs which feed the upper lake, may rank as a river where it leaves that body of water, but, in contrast with the Kootanie, is a stream with very gentle current, and may even be called sluggish in many places northward to the mouth of the Kicking Horse, where it passes beyond the limit of the present map. The amount of fall of the Kootanie River from the place at which it enters the valley to the forty-ninth parallel, is over 500 feet in a distance of eighty-five miles in a straight line; that of the Columbia, from the Upper Columbia Lake to the mouth of the Kicking Horse, is approximately, 200 feet, in a distance, similarly measured, of eighty-three miles. The distance between the head of the lake and the nearest point on the Kootanie River, is about a mile and a half, the intervening country being a flat terrace, and the water of the Kootanie being actually higher than that of the Columbia Lake by a few feet. The cause of this singular relationship of the two rivers will be referred to later.

Courses of the two rivers.

The Columbia-Kootanie Valley, as it now exists, has an average width of about five miles between the steep slopes of the mountains bounding it, and though in some places much wider, it is in the main, a great flat-bottomed, parallel-sided trough. Except in the vicinity of the steeper bordering mountain-slopes, solid rock seldom appears at the surface, and then generally as bosses or isolated masses rising to an inconsiderable elevation above the detrital deposits, by which it has been filled, which are evidently of great thickness. Regarded as a whole, however, the valley is widest in its southern part, and this constitutes one argument in favour of its original southern outflow. As an exception to the general character above given may be mentioned the existence of two ridge-shaped, longitudinal elevations which occur between latitudes 50° 30′ and 51°. These lie in the centre of the valley, west of the present position of the Columbia River.

Great width of the valley.

The detrital deposits which now floor the valley are markedly terraced at several different levels, which do not appear to preserve any

Detrital deposits in Columbia-Kootanie Valley.

great constancy in relative height. In a number of places, however, extending all the way from the 49th parallel to the northern edge of the map, collections of irregular mounds and ridges occur, which are almost certainly morainic in character, and very frequently the terraced surfaces are broken by groups of projections of the same class, more or less degraded by water action, and evidently partly buried in the later horizontal deposits. These, with frequent intercalations of sand and gravel, are largely composed of fine, pale silts, which show a tendency to form vertical bluffs along the streams, and are in some places almost pure white. Remarkable examples of this silt occur on the Columbia about three miles below the lower lake, on the Kootanie between the mouth of Tobacco River and the Elk, and elsewhere. Similar silts, forming probably part of the same formation, may be traced some distance up the Kicking Horse Valley, and in the valley of the lower part of the Wigwam, in which localities they reach a height of about 3,500 feet above the sea-level.

Secondary axial trough.

Since the terrace-forming epoch, however, a wide, depressed, flat-bottomed trough has been formed in the detrital deposits along the centre of the great valley, and the Kootanie and Columbia rivers, though in places impinging upon the edges of the higher terraces, in general follow a more or less tortuous course in the bottom of this secondary trough, which varies from about half a mile to a mile or more in width, and neither of these streams normally flow upon the actual rocky bed of the great valley. As elsewhere stated, there is reason to believe that deposits of later Tertiary age (probably Miocene) occupy part of the bottom of the wide valley of the Kootanie beneath the detrital deposits.

Origin of this great valley.

It would thus appear that the origin of the Columbia-Kootanie depression must be sought at a remote period of great or very long-continued erosion subsequent to the era of mountain elevation at the close of the Laramie, and the facts are in favour of the belief that the river producing it flowed to the southward. In later Tertiary times there was already a great valley, in which, owing to some change in relative elevation, stratified deposits were formed, and during the glacial period a portion of the ice accumulating on the adjacent ranges discharged southward by this valley. On the withdrawal of this great glacier, morainic accumulations were formed along its retreating edge and by smaller glaciers, at the mouths of the lateral valleys. At this time, or not long thereafter, owing to some combination of circumstances which we need not here pause to discuss, the valley was flooded to a considerable depth, and the white silt deposits—the material of which was directly due to the action of glaciers still existing in the neighbouring mountains—were laid down, the coarser intercalated

beds being doubtless produced near the mouths of lateral streams during times of flood.

When the body of water in which the white silts and associated deposits were formed was eventually drained, it is very clear that the river which then occupied the great valley again flowed southward, and produced the axial trough by erosion of the detrital deposits flooring the valley. The direction of the flow is well shown by the delta or 'fan' produced at the mouth of Dutch Creek, at the north end of the Upper Columbia Lake. This fan has been largely formed by the erosion of the white silt terraces, across which the stream flows near its mouth, and is quite lop-sided, tailing off to the southward in the direction of the flow in the main valley, while at a still later date the stream has cut a shallow gorge in the material of its own old delta deposit. Had the relative levels remained unaltered, is is uncertain whether the southward flow of the drainage of the valley would have been sufficient to maintain an uninterrupted waterway—as is still the case in that portion of the valley occupied by the Kootanie. The great quantities of coarse detritus brought in by the lateral streams would have a tendency, by interrupting this flow at various points, to produce a series of long lakes. The actual exceptionally light slope of the portion of the valley occupied by the Columbia, however, with the fact that the flow is now northward instead of to the south, favour the belief that a change in level occurred, by which the northern part of the district was relatively lowered, and that this, in conjunction with the great deposit formed by the Kootanie at the place at which it enters the valley, determined the present position of the watershed between the two streams, and reversed the direction of flow in that part of the valley now occupied by the Columbia. The Columbia lakes evidently occupy portions of the axial trough in the drift deposits which have been subsequently dammed off by the deposits of smaller lateral streams. From the lakes northward, all the way to the mouth of the Kicking Horse, the Columbia pursues a tortuous course through a series of morasses and lakelets which occupy this axial trough, the immediate borders of the river being generally marked by raised parallel banks supporting poplars, willows, and other trees, and separating the stream from the bordering swamps and ponds which render it in most places well nigh impossible of approach. The Kootanie, on the contrary, though flowing in the opposite direction in the continuation of the same axial trough, is bordered on alternate sides by grassy or partly wooded flats, which, though in places swampy, are frequently dry, or flooded only during periods of exceptionally high water.

Post-glacial southward drainage of valley.

Probable lowering northward.

Determination of position of watershed.

Glaciers and snow-fields.

Throughout the whole of this mountain region large patches of perennial snow are frequently met with at elevations surpassing 6,000 feet, and on northward slopes, and in retired valleys at lower heights. There are even some rather extensive snow-fields, but no large connected portion of the mountains rises to such a height as to show a well-marked snow-line. In the higher mountains near the forty-ninth parallel, masses of hard snow and ice exist which might be denominated glaciers, but further north, true glaciers occur, with all the well-known characters of those of the Alps and other high mountain regions. Such glaciers may be seen on the North Branch of the Kicking Horse, at the heads of the lakes forming the sources of the Bow, at the head-waters of the Red Deer and elsewhere, and are fed by snow-fields, the areas of which have not been accurately mapped, but must in some cases be very extensive.

At altitudes exceeding 6,000 feet, snow falls more or less frequently in every month in the year, and toward the first of October it may be expected to occur even in the lower valleys within the mountain region.

Differences in rain-fall.

In regard to precipitation, the circumstances differ remarkably in the different portions of this comparatively limited tract of mountains, the rain-fall being small in the Columbia-Kootanie Valley, heavy on the adjacent western slopes of the range, and again inconsiderable on the eastern slopes. The Selkirk and Purcell ranges, to the west, constitute a region of heavy rain-fall, and the position of the Columbia-Kootanie Valley in their lee, with reference to the prevailing westerly currents, explains the dry character of its climate. Meeting the western slopes of the Rocky Mountains proper, these air-currents are still sufficiently laden with moisture to give rise to the abundant precipitation of that region, but on passing still farther eastward, beyond the summit elevations, the conditions are unfavourable to further rain-fall. Superimposed, however, on these main features is a tendency to greater rain-fall toward the north, which is especially noticeable—whether from an increased elevation of mountain-barriers to the west or other cause—in comparing the conditions in different parts of the Columbia-Kootanie Valley.

Recent increase in rain-fall.

Evidence of a remarkable character has been found, which tends to show that a somewhat rapid increase in the total annual precipitation, has taken place during late years, and deserves to be recorded here. The evidence referred to is that afforded by the abnormal height of small lakes, without outlets, occurring in regions characterized by moraine hills. These serve as natural gauges, but instead of measuring the actual rainfall give a result, dependent on this and the counteracting effect of evaporation. The abnormal character of the rise of the water in these lakes is shown by the facts that it has killed a belt of trees, some of large size, and at least fifty years in age, along parts of the

margins of some of these lakelets. Both the Douglas fir and the yellow pine—the latter, never naturally growing even in damp soil,—have been found in numbers thus killed. The condition of the trees shows that they have been killed within a few years, and their size indicates that the waters of the lakes in question have not been for any considerable time during a period of fifty years or more, at the present high level. These observations were made both in 1883 and 1884. The lakelets observed to be so affected were numerous and scattered over a belt of country along the western part of the range for a length of about 140 miles; three of the principal districts at which such facts were noted being the Tobacco Plains, the Kootanie Valley between the Lussier River and head of Columbia Lake, and the upper valley of the Kootanie near the mouth of the Vermilion.

Heavy floods in 1884.

I noted also of the Columbia Valley south of the mouth of the Kicking Horse, in August, 1884, that most of the small streams coming from the mountains to the east showed marks of excessively heavy flood-water in the earlier part of the same year. This evidence was of such a character in relation to trees of great age which had been undermined, and belts of wood through which the water had rushed with devastating force, that I was led to believe that no such flood could have occurred for fifty or a hundred years previously. New channels cut out in old fan accumulations, revealed also layers reddened by forest fires, which must have occurred centuries ago, showing that destruction of the forest by fire was even then in progress. It may be added here that evidence of the same nature with regard to very old forest fires, was noticed in railway cuttings on the Kicking Horse Pass, and also in one place on the Bow River, where modern forests, at least a hundred years in age, were growing above the reddened layer, still holding pieces of charcoal, which evidenced the destruction of a former growth.

Ancient fires.

Vegetation an index of climate.

The character of the vegetation is the most important index of climate, and within limits in latitude so restricted as those of the region at present considered, the influence due to position on the earth's surface may almost be disregarded.

Vegetation of different districts contrasted.

In the region here described, the total annual precipitation is doubtless least in that part of the Columbia-Kootanie Valley near the 49th parallel, which is known as the Tobacco Plains. Much of the surface is there open, covered with bunch-grass and dotted with open groves of yellow pine (*Pinus ponderosa*), interspersed with the western larch (*Larix occidentalis*) and Douglas fir (*Pseudotsuga Douglasii*). While drought-loving plants such as *Purshia tridentata*, several species of *Artemisia*, the low-growing cactus, *Bigelovia graveolens* and *Balsamorhiza sagittata* abound. Northward, in the valley, these forms (with the

exception of the Douglas fir) gradually disappear. The western larch and yellow pine cease abruptly at the bend of the Upper Columbia Lake, and beyond this point, the shrubby and herbaceous plants enumerated are found only sparingly on dry slopes. The open woods characteristic of the part of the valley occupied by the Kootanie, are also replaced by denser forest, of which the black or scrub pine (*Pinus Murrayana*) and Engelmann's spruce (*Picea Engelmanni*) form a large part. Near the Columbia lakes and southward, irrigation is necessary for the growth of crops, but where this has been attended to, excellent results are obtained. Cultivation has so far been attempted on a limited scale, and in a few spots only, but mountain streams available for purposes of irrigation are, fortunately, abundant, and though much of the soil in this part of the valley is rather light, it will eventually become of some importance from an agricultural point of view, its lower altitude and consequent less prolonged and rigorous winter being in its favour.

Region requiring irrigation.

In the Flat-head Valley, the character of country described as occurring on the Kootanie is repeated to some extent, but in a less pronounced way, and a few miles north of the 49th parallel the valley becomes blocked by dense forests.

Eastern slopes.

On the eastern slopes of the mountain region, and particularly in the lower valleys of the foot-hills, and those traversing this part of the mountains, these conditions are again to some extent repeated; and even within the outer range, rather extensive dry prairie-patches and slopes covered with bunch-grass are found in the lower parts of the depressions of the various passes. Neither the western larch nor the yellow pine, however, re-appear on this slope, and the Douglas fir, though abundant in the foot-hills and as far east as the Porcupine Hills, does not climb many hundred feet up the mountain-slopes, and is wanting in all the higher valleys.

Characteristic trees and plants

The tree most characteristic of the valleys on the western well-watered slopes of the range is the western cedar, or arbor-vitæ (*Thuya gigantea*). This tree, though found only in a few places to the north, in the part of the Columbia-Kootanie Valley included in the present report, occurs in greater or less abundance in the lower part of all the mountain valleys opening westward, from the Kicking Horse to the 49th parallel, but was not anywhere observed to the east of the watershed. In the southern part of the district, the bracken (*Pteris aquilina*, var. *lanuginosa*), occurs in the same valleys. *Pachystima myrsinites*, a low, evergreen shrub, is very generally found in the same districts with the cedar, but flourishes as an undergrowth in woods and valleys even higher and cooler than those in which the cedar grows. It is scarcely ever found east of the watershed, and though a rather incon-

spicuous plant, is specially worthy of mention from the constancy with which it appears everywhere in British Columbia as a characteristic mark of a cool, moisture-laden atmosphere. The devil's club (*Fatsia horrida*), thriving in conditions of still greater moisture, was observed only in one place on the Kicking Horse (near the mouth of Porcupine Creek), in The Gorge of the Vermilion, in the deep valley of the Elk where that river breaks through the outer range, and in the Sinclair Pass—all retired and shaded spots on the west slope of the mountains. The western white pine (*Pinus monticola*) is found on the western side of the range, but never in large groves, and is confined apparently in the Rocky Mountains to the southern part of the district. *Pinus flexilis* occurs sparingly along the Bow River in the foot-hills and in the eastern parts of the valley of the South Kootanie and other passes. The cottonwood (*Populus trichocarpa*), balsam poplar (*P. balsamifera*), aspen (*P. tremuloides*), and birch (*Betula papyrifera*), occur along valleys on both sides of the range. The western birch (*B. occidentalis*) was observed on both sides of the range, but not within the mountains. The rowen (*Pirus Sambucifolia*), sparingly in one or two places.

Most abundant forest trees.

By far the greater part of the forest growth, however, of this portion of the Rocky Mountains is composed of Engelmann's spruce and the black pine. These are equally abundant and characteristic in all parts of the range, and in cool and sub-alpine localities become mixed with the western balsam spruce (*Abies subalpina*), which often forms extensive groves. More strictly Alpine in habit is the white-barked pine (*Pinus albicaulis*); and Lyall's larch (*Larix Lyallii*) abounds only at the upper limit of arboreal growth. It appears with the greatest constancy at an elevation of 7,000 feet, which may be considered as the timber-line, as about this height, even in localities otherwise well suited for the growth of trees, they cease to be able to maintain themselves, the slopes above supporting only low alpine and boreal plants. When the leaves of this little larch begin to turn yellow, in September, its zone of growth in some places may be traced by this colour with the regularity of a contour-line along the higher mountain slopes.

Plants collected

It was originally intended to include as an appendix to this report a list of plants collected in this part of the mountains, but during the summer of 1885, Professor Macoun visited that part of the region near the line of the Canadian Pacific railway, and procured much more extensive collections than I had been able to make in connection with my geological work. References to the species obtained are given in his Catalogue of Canadian Plants (now in course of publication), rendering any attempt at a complete enumeration of the plants

Species confined to southern mountains.

here unnecessary. Professor Macoun, however, informs me that a considerable percentage of the plants obtained by myself in the South and North Kootanie passes and mountains adjacent to them, are not met with in the part of the range in which he has collected, a number of mountain forms apparently not extending more than a short distance northward beyond the 49th parallel. This circumstance is probably explained by the greater humidity of the northern region, in connection with the partial break in continuity of the higher eastern ranges, which occurs about the head waters of the Old Man River. *Xerophyllum Douglasii* is a remarkable case in point, this plant being quite conspicuous in the South Kootanie Pass, but never found north of the Crow Nest Pass.

Trees characteristic of climate.

As differences in the composition of the forest growth of the various parts of the mountains form the most conspicuous indications of the different climatic zones, it may be useful to recapitulate the relative order in which the more abundant and constant trees met with in this region, naturally follow in this regard. This order is as follows.—

Larix Lyallii (Lyall's larch). Strictly Alpine.

Abies subalpina (Western balsam spruce). Alpine and sub-alpine, and extending downward to the higher and cooler valleys.

Picea Engelmanni (Engelmann's spruce) and *Pinus Murrayana* (black pine). Sub-alpine and extending downward.

Thuya gigantea (Western cedar). West slope only.

Pseudotsuga Douglasii (Douglas fir). Lower valleys on both slopes.

Larix occidentalis (Western larch). Base of mountains on the west.

Pinus ponderosa (yellow pine). Base of mountains on the west.

Deducting from this list *Thuya gigantea*, which appears to require a special degree of moisture in addition to other conditions, the order of enumeration proceeds from those trees tolerant of greatest cold and least warmth of summer temperature, to those which, though able to endure considerable winter cold, require a greater summer heat.

Destruction caused by forest fires.

Notwithstanding the evidence previously mentioned of the occasional occurrence of forest fires in ancient times in these mountains, it is only within the historic period for the region (probably not before the beginning of the century) that such fires became common, and during the past few years their frequency has increased in a greatly accelerating ratio. The effect of such fires is most disastrous. Large quantities of valuable timber are destroyed and whole regions become so blocked with tangled burnt woods and wind-fall as to be practically inaccessible, while the fine mountain scenery is seriously marred. These destructive fires in most cases arise through sheer carelessness or

wantonness and the most stringent measures should be taken to prevent them before it is too late. As the class of persons most careless in this respect is generally that least desirable to retain in any country, the authorities would find the respectable portion of the community in full sympathy with them in any measures adopted to check this evil. It is often stated that the Indians are responsible for much of this destruction, and it is doubtless true that since they find the whole region in process of being ravaged by fires which they can not prevent, they have become more careless than before. They would not, however, willingly destroy their own hunting grounds, and the best evidence of their care is found in the fact that, while along the North Kootanie Pass, (which so far has been scarcely used, except by the Indians,) the woods are generally unburnt, those in the vicinity of the parallel Crow Nest Pass, which has now been for a few years a route used by whites, are entirely destroyed and represented only by bleaching or blackened trunks.

Geological and General Description of the Region.

Mountains in the Vicinity of the Forty-ninth Parallel and near the South Kootanie Pass.

Previous explorations.

In treating of the geology and general features of this part of the mountains, as far west as the mouth of Akamina Brook, where my work in 1874, in connection with the Boundary Commission, may be said to have terminated, the description given in the Geology and Resources of the 49th Parallel will be in part quoted, with such additions as subsequent investigation render necessary. As already stated in the preliminary portion of this report, the South Kootanie Pass* was traversed in 1858 by Captain Blackiston, who was originally attached to Captain Palliser's expedition. He gives a map and profile of it in his report to the Imperial Government,† but has not furnished any geological notes. Mr. H. Bauerman gives some geological indications for this pass which will be found in his report, published for the first time in the report of the Geological Survey for 1882-84, together with some explanatory notes by the writer.

Character of mountains near 49th parallel.

Where intersected by the 49th parallel, the Rocky Mountains differ considerably in geological character from their northern extension, so far as included in the accompanying map. On this line the eastern

* Named the Boundary Pass on some maps, and also, from an alternative name of the Tobacco River in the Kootanie Valley, Grave Creek Pass.

† Further papers relative to the Exploration under Capt. Palliser, &c., 1860.

face of the range is very definite and wall-like, and in following the South Kootanie Pass, the rocks of the Cretaceous are not found to re-appear within the mountain region. Further north, particularly about the sources of the Old Man River, as first observed by the writer in 1881, the flexures of the rocks are such as to include long troughs of Cretaceous rocks, which divide the mountains into several well-defined subsidiary ranges, as fully described in connection with the northern passes. The rock exposures in the vicinity of the South Kootanie Pass are also particularly comprehensive and clear, rendering it possible, even with cursory examinations such as those of 1874, to correctly outline the main sub-divisions of the Palæozoic rocks. A remarkable spur or echelon range of the mountains, however, almost exactly coincides with the position of the International boundary line. Of this the remarkable peak known as Chief or Chief's Mountain* is the most prominent point, and though placed on Palliser's map on the boundary line, proved, when that line was accurately defined, to be nearly five miles south of it. The line, however, strikes into the hills and abrupt ridges surrounding its northern base, and then crossing the narrow valley of the Upper Belly River, passes over the Wilson Range, and bisects Waterton or Chief Mountain Lake, which lies at the foot of the principal range. The line thus runs for about fourteen miles through an outlying hilly and mountainous country, which by a detour of a few miles to the north may be entirely avoided, and waggons brought to the north end of Waterton Lake without difficulty.†

Remarkable spur.

Waterton Lake. Waterton Lake‡ is the source of the river of the same name which runs northward to join the Belly. It is separated, by a rocky spur of Sheep Mountain, into two parts, of seven and two and a half miles respectively in length. The first or upper portion is almost entirely surrounded by high and rugged mountains, while the northern part, making a right angle with the former, lies along the base of Sheep Mountain, and is bordered by low land to the north. A river of about a mile in length, leads from the lower end of the lake to a third expansion, of about two miles in length, which is surrounded by low hills only. The average width of these lakes is about three-quarters

* *Nina-stokis* of the Blackfoot tribes. Doubtless the same with "The King" of Arrowsmith's map of 1795.

† In the Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean, Vol. I., p. 549, Mr. James Doty, in his report of an exploration northward, from Benton along the base of the Rocky Mountains, in 1854, describes as Chief Mountain Lake a lake which may be that at the head of the St. Mary River. It is certainly not the Waterton or Chief Mountain Lake of later maps. From his description it appears almost certain that the river, which he followed northward to about latitude 49° 30', was that now known as the St. Mary.

‡ Named *A-kwote-katl-nam* on the map of the first Boundary Commission.

of a mile; the water is deep and clear,* and the scenery in the vicinity is not excelled in grandeur and beauty by that of any part of the mountains.

The rocks exposed in the mountains near Waterton Lake, and in the adjacent portion of the South Kootanie Pass, embrace the greater part of the section represented in the entire region. The total thickness of the beds here shown, was estimated, in 1874, at 4,500 feet; and though this must be regarded as an approximation only, it is probably not far from the truth. The local section is thus given in my previous report, in descending order, the supposed age of the various portions of the series being added.— General section

Probably Triassic or Permo-Triassic.

H.—Fawn-colored flaggy beds, seen only at a distance, but probably composed of magnesian sandstones and limestones. 100 *feet.*

G.—Beds characterized by a predominant red colour, and chiefly red sandstone, but including some thin, greyish beds and magnesian sandstones. The whole generally thin-bedded, though sometimes rather massive. Ripple-marks, etc. Weathers to a steep rocky talus where exposed in the mountain sides. Passes gradually down into the next series. 300 *feet.*

F.—Fawn-colored, flaggy beds of magnesian sandstone and limestone. Some red sandstones occur throughout, but are especially abundant toward the top. Apparently a continuation upward of the limestone D, and only separated from it by the trap outflow. 200 *feet.*

E.—Amygdaloidal trap; (Diabase) dark-colored and hard. 50 *to* 100 *feet.*

Carboniferous and Devonian.

D.—Compact bluish limestone, somewhat magnesian, and weathering brownish. This forms some of the boldest crags and peaks of the mountains, and rests unconformably on Series C. 1,000 *feet.*

Cambrian.

C.—Sandstones, quartzites and slaty rocks of various tints, but chiefly reddish and greenish-grey; the individual beds seldom of great thickness, and the colour and texture of approximate beds rapidly alternating. In this series occurs a band of bright red rocks of inconstant thickness, also two or more zones of coarse magnesian grit. 2,000 *feet or more.*

B.—Limestone, pale-grey, cherty, and highly magnesian, hard, much altered and weathering white. It includes at least one band of coarse magnesian grit, like that found in the last series, which weather, brown. 200 *feet.*

A.—Impure dolomites and fine dolomitic quartzites; dark purplish and grey, but weathering bright brown of various shades. 700 *feet or more.*

* Capt. J. F. Gregory states that at a distance of 300 yards from the west shore, where intersected by the 49th Parallel, he was unable to reach bottom with a line 300 feet long. Capt. Gregory gives a detailed map of the shores of the lake in his report. Survey of Northern Boundary of United States.

Rocks near Waterton Lake.

Disregarding for the present the eastern outlying mountains above referred to, I shall describe the rocks seen in the vicinity of Waterton Lake. The lake is at an elevation of about 4,245 feet above the sea-level. The mountains surrounding it are often 8,000 feet above the same datum, and, like most of those in the eastern part of the range, are singularly bare and rocky and afford fine sections, even as viewed from a distance. They form a number of high ridges, which, on both sides, abut nearly at right angles on the lake shores, and are separated by deep intervening valleys. These ridges are as a rule capped by the massive limestones of series D, which are nearly horizontal, and rest upon the part of the Cambrian series which in the preceding table has been denoted by the letter C. At The Narrows, where the lake

Series A.

makes a bend, both shores are composed of rocks of series A, which appears to be brought to the surface by a low, irregular anticlinal flexure which crosses the lake in a north-west and south-east direction. The dolomitic rocks, which, for convenience of reference, have been denoted by the letter A, present a very remarkable appearance in the bare mountain sides, from the peculiarity of the tints assumed by them on weathering, which are for the most part bright reddish and yellowish browns, and alternate in broad belts according with the stratification. The bedding is very regular, and is marked, besides the difference in tint, by the erosion of some softer layers composed of thin, flaggy beds, which alternate with massive, compact layers several feet in thickness. The fracture of the more massive portions is conchoidal, with a dim lustre, and the colours of freshly broken surfaces are much less marked than those of the exterior, varying from light to dark grey, dull purplish and, in some cases, pale greyish pink.

The structure of the rock is generally very close and fine, and from the preponderance of sedimentary matter, it frequently resembles more a hardened argillite than a true dolomite. It does not effervesce in cold dilute acid, but on heating gently, a brisk action is induced, and when the whole of the calcareous and magnesian matter has been removed, there remains a coherent though tender mass composed of argillaceous and siliceous particles. The exposed surfaces are generally decomposed to a small extent.

Of these rocks, at least seven hundred feet in thickness is exposed. They are well shown at the cascade* on the western shore of the lake, but to the south soon dip out of sight, the overlying beds coming down to the water-level. In 1874, and again in 1883, careful search was

* One mile from The Narrows. Called Cameron's Fall on plate opposite p. 312, in Survey of Northern Boundary of United States.

made in these rocks and also in the higher members of the Cambrian of this vicinity for fossils, but without success.

Series B. Resting directly on these peculiar dolomites is a very massive bed of limestone, also dolomitic, which forms a prominent feature from the chalky-white aspect of its weathered surfaces. It is designated by the letter B, in the general section previously given, and is about two hundred feet in thickness. It includes at least one well-marked band of coarse magnesian grit. The limestone, on fresh fracture, is of a pale grey colour, very close-grained and compact, and breaks with a splintery fracture, the original planes of deposition being almost entirely lost. Some layers are exceedingly cherty, the silicious matter being in places aggregated into well-defined nodules, but more usually disseminated, and forming an irregular skeleton, which gives to some weathered surfaces an exceedingly rough appearance. With acid, the rock scarcely effervesces in the cold, but on heating is rapidly dissolved, leaving a comparatively small amount of residue, which, under the microscope, seems not to be of a detrital nature, but to bear the form of minute concretions produced by the rearrangement of the silica. This limestone appears to be perfectly conformable with the rocks of series A and C, below and above it; constituting, in fact, merely a subordinate portion of this great Cambrian formation.

Series C. The rocks designated by the letter C, which overlie the last, are well exposed in the bare sides of the mountains on both shores of the northern end of Waterton Lake. On the east side they form a great portion of the west side of Sheep Mountain,* while to the west a mountain, rising about 4,000 feet above the lake and extending to the entrance to the South Kootanie Pass, is almost entirely composed of these beds, which have there been subjected to violent flexure. As a whole, this division of the section may be described as consisting of quartzites and hard quartzose sandstones, slates and shales; and its most remarkable feature is the rapid alternation of beds differing in colour and texture. Various shades of green, purplish-brown, red, and white are most prevalent.

Sheep Mountain. In the almost vertical western side of Sheep Mountain, the total exposed thickness of beds of series C, must be about 2,000 feet. These rest directly on the limestone B, and are overlain by the limestone series D, the latter resting with evident unconformity on them. This unconformity is shown very clearly by the existence of a thick belt of bright red rocks, forming a part of series C, which is observed to run out altogether beneath the upper formation at one end of the mountain.

*Referred to as Mount Wilson in the Geology and Resources of the 49th Parallel. It has since become known locally as Sheep Mountain, and the former name is perhaps more appropriately applied to the entire outlying range of which this peak forms a part.

Section in Sheep Mountain.

In 1881, Mr. R. G. McConnell, then acting as my assistant, ascended Sheep Mountain and measured the following section on its northern side, including part of the capping beds referred to the Devonian or Carboniferous limestone series (D) and a considerable portion of series C. The section is as follows in descending order:—

	FEET.
1. Greenish-white, rather coarse-grained sandstone, moderately compact, in beds 3″ to 1′ thick	45
2. Greenish-white sandstone, weathering to a light yellowish colour, in beds 1″ to 3″ thick. Rather compact	30
3. Greenish shales	70
4. Red shales	20
5. Green shales	15
6. Greenish sandstones	20
7. Light-greenish shales, very hard, and passing into quartzite in some places	80
8. Yellowish sandstones, somewhat flaggy and ripple-marked	60
9. Light-yellowish sandstone in beds 1′ to 2′ thick, alternating with thin beds of dark shale	85
10. Drab-coloured limestone in beds 1′ to 2′ thick, greatly flexed in some places, conformable with beds above, but unconformable with rocks below	355
11. Green shales, schistose in places, alternating with occasional beds of coarse, grey sandstone, some of the upper beds reddish	75
12. Bright red shales, holding occasional beds of greyish and reddish sandstone, greenish shales and jaspery conglomerate, some beds of sandstone ripple-marked	700
13. Greenish and reddish shales alternating with some grey sandstone	300
14. Fine-grained, greenish-white sandstone, weathering light yellow, some of the beds very hard and passing into quartzite 100′ or more	100
	1,955

The beds from the summit to No. 10 inclusive are referred to series D. The appearance of so great a thickness of sandstones and shales with the limestone series is exceptional, though sandstones and quartzites of considerable thickness are found in association with it in some other parts of the mountains.

Wilson Range.

The outlying or counterfort range, situated to the east of Waterton Lake, and designated the Wilson Range, has a width, from west to east, between the lake shore and the upper part of the Belly River, of seven miles. Its western side and north-west angle is Sheep Mountain. Several of its summits and ridges, a short distance south of the 49th parallel, reach 9,000 feet in altitude, and its highest peak, situated about three

miles south-east of the upper end of Waterton Lake, reaches a height of 10,535 feet above the sea.* As viewed from the north, the front of the Wilson Range is chiefly composed of the rocks of series C, in which the bright red band, before described, is conspicuous in several places. The central and higher parts of the range are of the limestone and associated rocks of series D. Rocks differing in appearance from the rest, and apparently brought up by a fault, occur at the north-eastern corner of the range. These were seen from a distance only, but may represent those of series B.

CHIEF MOUNTAIN, FROM THE NORTH, ABOUT FOUR MILES DISTANT.

Chief Mountain

Chief Mountain, which projects still further to the eastward, is one of the most remarkable mountain masses of this region. It is nearly isolated from the rest, though surrounded by rugged foot-hills, which are covered with dense woods and wind-fall, rendering it very difficult of approach. As seen from the eastward, it resembles the base of a broken column, and from this point or from the north it may be recognized from a distance of over a hundred miles. On three sides, the central mass of the mountain is precipitous, and its bare rocky cliffs are of great height. To the west it appears to slope more gradually, and its summit is cleft by deep ravines. The perpendicular, central portion is composed of the limestones of series D, in a nearly horizontal attitude, but broken off abruptly on all sides along jointage planes. The rocks of the foot-hills are softer and no doubt belong to series C. In the Crow's Nest and other mountains to the north, similar forms, dependent on the same geological conditions, are reproduced.

* Named Kaiser Peak on Captain Gregory's map referred to in a previous note, and stated to be 6,290 feet above the lake. In the height above given the revised elevation of the lake is added.

South Kootanie Pass.

Entrance to the pass.

The South Kootanie Pass has been from time immemorial one of the chief routes used by the Indians in crossing the mountains, and till a few years since was annually traversed by the Kootanies when on their way to hunt the buffalo on the eastern plains. Like most of the main valleys in the eastern part of the range, this is for some distance not thickly forested, and is characterized by wide grassy flats and open slopes. Country of this character extends from the eastern mouth of the valley to 'The Forks,' a distance of seven miles. There is scarcely any more striking view to be found in the mountains than that obtained from the hill over which the trail runs at the entrance of the pass, from which the eye follows the great trough-like valley for many miles to its termination at the base of the summit ridge. At the forks above referred to, two streams of nearly equal size unite to form that which flows into Waterton Lake, and is generally called the Kootanie Brook, though named the *Kin-nook-kleht-nan-na* on the map of the first Boundary Commission. Above the forks, both valleys may be described as generally wooded. The trail follows the southern branch, keeping on the northern side of the stream, passing along some rough hillsides and in one place winding between huge blocks, which have fallen from the neighbouring mountain. At about five miles from the forks, the trail begins the ascent of the summit ridge, and in a short distance emerges on bare, rocky slopes, which pack animals surmount with difficulty by a series of steep zig-zags. The watershed ridge has here an altitude of 7,100 feet, very nearly.* Both to the north and south of the point at which the trail crosses the summit ridge, its eastern face is extremely abrupt, consisting of rugged precipices of great height. Along its western side the descent is more gradual, and nearly follows the dip of the strata composing it. From the summit it may be observed that a number of the mountains both to the east and west of the watershed are much higher than the axial crest.

"The Forks."

Summit.

Rocks of eastern part of pass.

The following description of the rocks met with in the eastern portion of the pass is taken with little alteration from my report of 1875, previously referred to. The edition of this report, published in connection with the Boundary Commission, having been limited, it is now completely out of print.

The rocks forming the mountains on both sides of the pass to the base of the watershed ridge have a general light westward dip, and

* In the Geology and Resources of the 49th Parallel its height is given as 6,673 feet; by Capt. Blackiston, from a single observation, 6,030 feet. The above is believed to be much more nearly correct than either of these. It is the mean of observations made in 1881 and 1883.

LOOKING SOUTHWARD ALONG EAST SLOPE OF SUMMIT RIDGE, S. KOOTANIE PASS.

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comprise the entire series in ascending order from C to F, both inclusive. An extensive fault, with north-west and south-east direction and downthrow to the north-east, evidently runs along the valley at the eastern base of the watershed ridge, and here breaks the continuity of the section.

Subdivisions of series C.

The beds of Series C, are well displayed in the sides of the eastern part of the pass, and were there separated, for convenience of reference, into five sub-divisions.

The rocks at the entrance of the pass have a general south-westward dip. The lowest seen are in the bed of the brook, and must be well down in the series. They consist of very hard, greenish shales and compact, thin-bedded quartzites. In the mountain on the north side, they were seen to be overlaid by reddish, greenish and bluish-grey sandstones, with some shaly beds, all much hardened, but forming a talus and not well exposed. These were designated sub-division 1.

Magnesian grit.

About midway up the same mountain, a massive bed of magnesian sandstone or grit appears, and constitutes sub-division 2. It must be about fifty feet in thickness, and great blocks which have broken from it are now strewn along the slope and encumber the pass. It evidently corresponds to one of the similar beds described as occurring on Waterton Lake, and lithologically also bears a close resemblance to that included in series B. It is composed of large, well rounded grains of transparent quartz, with occasional darker particles —the whole imbedded in an opaque, white calcareous and magnesian matrix, which turns brown on exposure to the weather.

Next in the series, and forming the summit of this mountain, is a considerable thickness of red, greenish and bluish-grey sandstones and shales, which, by their alternation, give the cliffs a curious banded appearance. They resemble those of the first sub-division, and may be named sub-division 3.

Red rocks

On the opposite mountain, on the south side of the pass, a series of bright red beds appear overlying the last. This constitutes sub-division 4, and is the same with that already noticed as occurring in Sheep Mountain and elsewhere in the Wilson Range. In following the trail westward, this zone is found to come down almost to the level of the brook, at about a mile and a quarter from the entrance of the pass. Its thickness at this place must be about two hundred feet, and from the exceedingly bright colour of the beds, it constitutes, wherever it occurs, an excellent reference horizon, and may often be detected even at a great distance. The beds composing this sub-division are hard, red, thin-bedded sandstones, with frequent thin intercalations of red argillaceous material, and one or two minor beds composed of pale greenish, shaly quartzite. A fifth sub-division, which intervenes in some places

between the red beds and the base of the limestones above, is not well seen in this part of the valley.

Series B.

At about three miles from the entrance to the pass, in the bottom of the valley, and near the brook, are rocks, which though not closely examined, appear to belong to the limestone series B. These are probably continuously exposed in the valley which runs through to Cameron's Fall on the lake, being brought up along the axis of a low anticlinal.

The mountains about the head of the valley, which runs north-westward from the forks, afford fine sections and would merit careful examination in connection with the beds overlying the limestone series D, which, are there well exposed. A very remarkable ridge-like mountain lies in the angle between the two streams, and, as seen from the main valley, has a sharp conical outline. This, on the map, I have named Anderson's Peak, in memory of the late Major S. Anderson, R.E., Chief Astronomer of the second Boundary Commission, and also a member of the first Boundary Commission expedition already referred to.

Anderson's Peak.

Rocks near The Forks.

In following the valley of the southern stream, the trail, after crossing the northern branch, runs for about half a mile parallel with the axis of a gentle anticlinal, which has an east-and-west course, and passes eventually into the ridge-like mountain in the angle. In the bed of the brook, and well down among the variegated sandstones and quartzites of sub-divisions 1 or 3 of Series C, is an extensive exposure of coarse trap. It is not certain whether this is an interbedded mass or an intrusion. Over twenty feet in thickness is exposed. The rock is dark-colored and compact, and some large, loose fragments which appear to have been derived from the same bed, show remarkable stellar aggregations, several inches in diameter, of pale-green felspar crystals. Below the trap, and in the bed of the brook, an extensive series of banded red and green sandstones and quartzites appears. These beds all lie at low angles, and are not much disturbed, though somewhat corrugated on a small scale. A species of shaly conglomerate is here also not uncommon, though generally occurring in beds only a few inches in thickness. This rock is essentially a greenish, white or reddish quartzite, which encloses small, irregular fragments of green or red fine-grained shaly rock. The included shale-fragments resemble some beds found in the same series, and are probably the result of slight contemporaneous erosion. These peculiar conglomerates are not uncommon at several horizons in series C, and fragments of them have been recognized among the drift deposits far out on the plains.

The upper part of the mountain already referred to as Anderson's Peak, which occupies the angle between the two streams, is com-

posed of the thick limestone beds of series D of the general section. These weather light brown or fawn-colour, and constitute the summits of the higher mountains on both sides of the pass. When, as in this instance, they form the crest of a peak or ridge, disintegration proceeding most rapidly along vertical lines of jointage, produces extremely picturesque and rugged outlines. When, however, merely exposed in the side of a mountain and still covered by other beds, they form steep terraced slopes or vertical cliffs of quite different aspect. The lower beds of the limestone in this vicinity are much more massive than the upper. Mount Blackiston, the towering mountain to the south, on the opposite side of the valley, probably includes the whole thickness of series D, with a small outlyer at the summit of series E, the contemporaneous trap.

Forms of limestone mountains.

At about three miles above the forks, the general westward inclination of the rocks brings the base of the limestones down to the bottom of the valley, while the contemporaneous trap, above referred to, appears at about the same place, capping the limestones in the mountains on the north side of the valley. The trap must here be at least fifty feet in thickness, and great masses have fallen from it into the valley below. The rock is greenish, purplish or brown in colour, and shows numerous amygdaloidal cavities. It is probably a diabase, though under the microscope it appears much decomposed. Series F and G also occur overlying the trap in the summit of the mountains in this vicinity, but were not here examined.

Bedded trap.

The rocks forming the watershed ridge, and seen on the trail from its eastern base to about three and a half miles beyond its summit, appear to belong entirely to series C. The fault previously referred to as probably running along the eastern base of the ridge was not actually observed, but the relations of the beds leave little doubt of its existence, and show also that a similar fault, but with a down-throw on the west side, must cross the valley of the trail, at the distance above stated, west of the summit—the summit ridge thus consisting of Cambrian rocks bounded by down-throw faults to the east and west. The steep ascent from the valley at the eastern base of the ridge is about 1,022 feet; on the west, a little brook is crossed at about three-quarters of a mile at an elevation 1,325 feet lower than the summit, or 300 feet below the stream last crossed on the east side. The rocks of series C, here met with, dip at low angles to the west or north-west. Red sandstones are abundant on the eastern slope, while greenish and grey schists and quartzites preponderate on the western.

Rocks of watershed ridge.

Near the point above defined as three-and a half miles from the summit, the valley of Akamina Brook joins that of the pass, from the southward. This valley was that followed both on the first and second

Akamina Valley.

Boundary Commission expeditions for the purpose of reaching the terminal monument marking the intersection of the 49th parallel with the watershed. The rocks observed in this valley and near the monument will be noticed before the description of the main section on the Kootanie Pass to the westward is continued.

Akamina Brook.

Rocks in neighbouring hills.

The valley of Akamina Brook runs up south-eastward almost directly toward the position of the terminal boundary mon[illegible]t on the watershed. The rocks exposed in the sides of the valle[illegible] chiefly red, or reddish sandstones, generally rather thin-bedded, but sometimes massive. They belong, for the most part, to the upper red series G. Series H, composed of flaggy, fawn-coloured beds, which are no doubt magnesian limestone or sandstone, form the soft-outlined and crumbling summits of some of the mountains on the south-west side. These rocks (the highest observed in this part of the mountains) were not closely examined. Though a greater or less thickness of them was frequently seen resting on series G, and differing from it markedly in colour, it was always at a great height above the valleys.

Camp Akamina

The spot known as Camp Akamina, the eastern terminal station of the old North-west Boundary Commission, is situated at the head of the valley just described. It has an elevation of about 6,000 feet above the sea, and is a sheltered hollow with thick st[illegible]ge woods of fine growth. The Akamina Valley terminates jus[illegible]th of the 49th parallel in a fine, though small, cirque, holding a [illegible]e tarn which is rimmed with shattered blocks of limestone. The terminal monument of the first Boundary Commission expedition stands in a saddle-shaped depression of the watershed ridge, walled in on two sides by high, rocky peaks, while the other two are bounded by an almost precipitous descent. Its altitude is 7,056 feet, according to observations of the first Boundary Commission. Far down, on the east side of the ridge, is a lake about a mile in length, from which flows the brook forming the Cameron Fall on Waterton Lake. In the opposite direction the view extends for eighteen miles down the valley of the Kintla Lakes, which are overhung by gigantic precipices and thickly-wooded slopes. Few landscapes to be met with in the mountains surpass those of this vicinity in grandeur.

Summit monument.

Rocks near summit monument. Series F. & G.

Near Camp Akamina the rocks are red sandstones, but are not well shown or regular in position. In the mountain side between the camp and the boundary monument, however, the rocks are well exposed, and here the character of series F and G of the general section was best seen, and over six hundred feet actually examined. The

section here embraces the lower beds of series G, and the whole of series F. The highest beds examined consist almost entirely of flaggy, dull-red, compact sandstones, which are frequently ripple-marked. Above these, about two hundred feet of similar reddish beds is visible in distant hill-sides, and these again are overlain by the upper fawn-coloured series H. In descending, from the beds first mentioned, the red begin to alternate with grey and fawn-coloured sandstones, the latter magnesian, and white on fresh fracture. Lower in the section, while red and purplish-red sandstones still continue, whitish and fawn-coloured limestones—frequently concretionary—are intercalated, and become thicker and more frequent toward the base. The lowest rock seen in series F, is a dark-purplish sandstone, and not far beneath it, is the trap designated in the general section by the letter E. Many of the sandy beds throughout the entire section are ripple-marked, and rain pitting and sun cracks are not infrequent. At several different levels, too, the surfaces of sandstone beds show impressions of salt crystals, which have subsequently been dissolved and replaced by clayey matter. Some of these are as much as half an inch in diameter, and exhibit distinctly the peculiar hopper-shaped forms characteristic of sodic chloride.

Ripple marks and impressions of salt crystals.

The division made between series F and G, and that between G and H, are probably not of great importance. No unconformity obtains, and very similar conditions of deposition appear to have prevailed throughout, the deposition of reddish sandstone alternating with that of pale dolomitic sandstone and magnesian limestone. The divisions are therefore recognized as a matter of convenience only, and are founded on the different colours of the zones as they appear in the mountain sides.

Relations of upper members of section.

The trap E is still important at this place, though not so thick as in some other localities. It is dark-purplish in colour, and full of irregular amygdaloidal cavities, which are lined with green chloritic matter and generally filled with white calcite. Here, as elsewhere, it overlies the great limestone series.

South Kootanie Pass (Continued).

Akamina Brook is, as already mentioned, a tributary of the main stream followed by the South Kootanie trail. This stream, is on the map of the first Boundary Commission named Kish-e-nehn Creek. My observations in connection with the Boundary Commission extended only a few miles below the mouth of Akamina Brook, from which place the main valley runs nearly due south-east for about twelve miles to its junction with the Flat-head River, the total descent in that distance being about 700 feet.

Kish-e-nehn Creek.

Character of valley.

Below the mouth of the Akamina, the valley passes between two imposing mountain masses, named Mount Yarrell, and Mount Kirby and Spence, probably by Capt. Blackiston. For about five miles it is bordered on both sides by high mountains, rugged and bare about the summits; but beyond that point, lower wooded hills appear, which gradually decrease in elevation, and at the same time retire to a somewhat greater distance, the valley becoming more open. For the first five miles the trail is pretty rough, and the valley is generally wooded or encumbered with burnt forest. Further down there are some meadows, with good pasturage, and near the Flat-head River, a very pretty little prairie. At about three miles from the Flat-head, the trail crosses the forty-ninth parallel, where the observing posts and camping place occupied by the first Boundary Commission, in 1861, are still noticeable.

Trees.

Pinus flexilis (?) was observed growing with *P. Murrayana* on the river flats as far down as the mouth of the Akamina. A short distance further down the valley, the white birch (*Betula papyrifera*) was first seen, together with small specimens of larch (*Larix occidentalis*). Large specimens of the latter tree become common several miles east of the Flat-head Valley.

Fault west of watershed.

The fault previously referred to as probably bounding to the west the rocks of series C, which compose the region about the summit of the pass, must cross the valley about four miles west of the watershed. At about four and a half miles, rocks evidently belonging to series C, are exposed, dipping N. 43° E. $< 45°$, or nearly the reverse of that met with at the last exposures to the east referable to the same series. The rocks are flaggy, red sandstones, often beautifully ripple-marked. To the south-west they are followed by the fawn-colored, shaly dolomites of series F, and these again by the contemporaneous amygdaloid which must here be at least fifty feet thick. Following this in regular descending order is the great limestone series (D) of the general section. The outcrop of this limestone is about a mile wide where it crosses the valley, the dip at an average angle of about 45°, and the thickness here probably at least 4,000 feet. The upper part of the limestone, immediately below the trap, is shaly and dolomitic, like that overlying the trap bed, but becomes flaggy and thicker-bedded in descending, and passes into a peculiar dolomitic limestone, which has apparently been shattered and re-cemented by ordinary non-magnesian, grey-weathering limestone. It is probable, however, that this appearance is really due to a segregative action. This is followed by limestone which shows many broad, rounded, concretionary surfaces of an almost botryoidal aspect, and this again by an ordinary fine-grained crystalline limestone. No trace was here observed of crinoidal limestone or of fossils of any kind, and the whole limestone series appears to be more or less dolomitic in character.

Series F. & E.

Limestone series.

In Mount Yarrell, on the north-west side of the valley, the great limestone series is a prominent feature, and is overlain by series E, F and G. These all dip uniformly to the north-east, forming a comparatively gentle slope in that direction, while the south-west side of the mountain is scarped and steep. The trap (E) must be about 100 feet thick in Mount Yarrell. Mount Kirby and Spence, on the opposite side of the valley, with a height of 9,290 feet, has an analogous structure, its highest points being composed, however, of limestone, while the higher series appear only on its north-eastern flanks. All the south-western and lower summits of this great mountain mass, are composed of the Cambrian rocks, above referred to as series C. These also form the south-western base of Mount Yarrell, and their line of junction with the overlying limestones crosses the valley at a point about six miles from the watershed. Mount Yarrell and Mount Kirby and Spence.

The Cambrian rocks here underlie the limestone series without any well-marked unconformity, the first beds met with being greenish and grey quartzites, and hard quartzose and argillaceous shales. These are followed in descending order by a contemporaneous trap, which is amygdaloidal, and much resembles that which constitutes series E in the general section. The trap at this place was the first found in association with the Cambrian in this district, but similar contemporaneous flows were subsequently discovered in these rocks in a number of places. Below the trap is a thick series of sandstones and shaly beds with a conspicuous red colour, though including also beds of white quartzite and some greyish, hard shales. These beds have, in some places, almost a ribband appearance, and in one part of the base of Mount Kirby and Spence are corrugated by a series of small plications. The last rocks seen in place in this valley are nearly opposite the termination of the high mountains above referred to, and must be far down in the Cambrian. They are grey and blackish, fine-bedded sandstones and sandy argillites, highly calcareous; and though not unlike some of the beds of series A, seen on Waterton Lake, they do not, like these, weather to bright brown colours. Careful search was made in these beds for fossils, but without the least success. The minimum total thickness of the rocks underlying the great limestone series—all probably referable to the Cambrian—must be about 11,000 feet. The dip is throughout uniformly toward the north-east at angles seldom less than 30 degrees. Contemporaneous trap in Cambrian. Character and thickness of Cambrian.

The point at which the Kish-e-nehn enters the Flat-head is about three miles south of the International boundary. It was intended to follow the Flat-head Valley northward to its head, to connect with the traverse previously made by the North Kootanie Pass, but this proved to be so extremely difficult, owing to the dense character of the forest Flat-head Valley.

and the numerous tangled wind-falls occurring in it, that after spending two days in making a total distance of about ten miles, it was abandoned, and a return effected to the mouth of the Kish-e-nehn. A few days hard work would doubtless have enabled us to reach the northern pass, but the wide Flat-head Valley afforded few exposures, and the atmosphere, during this part of the season (1883), was so densely laden with smoke that the mountains bordering it were completely obscured and very little useful work was possible.

Vegetation. The valley, so far as examined, is floored by wide-spread, gravelly and sandy terraces, and for about two miles north of the boundary line is diversified by numerous little grassy prairies. Further north it is almost entirely wooded, the flats being characterized by cotton-wood and spruce, the terraces covered with a thick growth of *Pinus Murrayana*. A few very large and many small larches (*Larix occidentalis*) and some Douglas firs (*Pseudotsuga Douglasii*) also occur. Near the boundary line, thickets of *Artemisia tridentata* were observed, and this appears to be about the northern limit of a part of the valley having a relatively very dry climate. The river-bed is wide and stony, and the river swift and often split up into numerous sloughs and side channels.

Tertiary rocks. Rounded fragments of Cretaceous rocks are abundant in the river-bed, but were not seen in place. Tertiary rocks, resembling those assigned to the Miocene in the central plateau region of British Columbia, were met with in one or two small exposures in the bed and banks of the river, but poorly displayed and much disturbed by slides. They consist, so far as seen, of hard pale clays and sandy clays. It is probable that they underlie a considerable part of the width of this great flat-bottomed valley, though their extension to the north and south is quite indeterminate.

Pass west of Flat-head. The wide, longitudinal depression occupied by the Flat-head River separates the Rocky Mountains, in this portion of their length, into two parts. The elevation of the Flat-head, where it crosses the 49th parallel, is about 4,000 feet. The trail crosses it three miles south of this line, at a ford, which, though easy at low water, would be impracticable at high water. From this point the trail continues westward to the Kootanie River, near the 49th parallel, but a few miles southo f it all the way. It first follows up the valley of the Yak-in-i-kak Creek, of the map of the first Boundary Commission, to a summit at an elevation of 5,280 feet above sea-level, at a distance from the Flat-head of thirteen miles. Thence it descends to the Kootanie by the Tobacco River, (named Ak-o-no-ho Creek on the Boundary Commission map, and sometimes locally known as Grave Creek) for twenty-three miles, the total fall to the Kootanie being about 2,800 feet.

On leaving the Flat-head, the trail runs for about two miles southward across wide gravelly terraces covered with *Pinus Murrayana*, to the bank of the Yak-in-i-kak, where it turns westward. Numerous little prairies occur in the valley of the stream, for about four miles, beyond which the mountains, which have gradually been approaching it and increasing in height, crowd closely upon it, and it becomes everywhere densely wooded. About a mile further on, the trail leaves the bottom of the valley, and climbing far above the stream, passes along a steep and wooded mountain-side on the right, the valley itself being here cañon-like and impracticable. This very narrow and rugged portion of the valley, continues for about two miles, when it becomes somewhat wider, and the trail, gradually ascending, follows it, for the most part through woods, though occasionally on rocky slopes, on to the summit. The mountains increase very gradually in elevation from the edge of the Flat-head Valley, and everywhere present rounded outlines, tree-clad to the summits. Just east of the watershed, is a pretty little alpine meadow, from which the trail ascends steeply for a few hundred feet to the actual summit, passing there through a remarkable, dry, rocky notch between the mountains. In descending the Tobacco River, the trail is in some places rough and the valley is wooded till the western edge of the wide Kootanie Valley is reached. The mountains are everywhere rounded in form—differing much in this respect from the rugged outlines of the range east of the Flat-head—and are generally wooded to the summits.

Yak-in-i-kak Creek.

The character of the vegetation in this western range indicates a much more abundant rainfall than in the eastern. *Abies subalpina* becomes abundant and large in the valleys, and a few specimens of *Pinus monticola* are met with. The larch is seen occasionally in the valleys, both east and west of the summit, but this tree is not abundant or large, till the edge of the wide valley of the Kootanie is reached. About four miles west of the summit, the Cedar (*Thuya gigantea*) and bracken (*Pteris aquilina*, var. *lanuginosa*) appear simultaneously. *Pinus ponderosa* is first seen at the edge of the Kootanie Valley, where with the larch and Douglas fir, it forms open groves of fine growth. *Pachystima myrsinites*—everywhere in these mountains characteristic of a cool, damp climate—disappears nearly at the point at which *Pinus ponderosa* first occurs. *Xerophyllum Douglasii* is abundant along almost the entire length of this pass. The cross-sections of the mountains by the various passes included in the present report offer very similar features in regard to the distribution of trees and characteristic plants, though in this case complicated by the intrusion mid-way of the dry Flat-head Valley.

Vegetation indicating abundant rain-fall.

Observations of Mr. Geo. Gibbs.

Mr. George Gibbs, in the geological notes included in his paper already mentioned* gives a description, in outline, of the geological features of the South Kootanie Pass, and refers to that part of the trail between the Kootanie and Flat-head with more than usual detail. His observations on the general appearance and lithological character of the rocks are quite correct. Mr. H. Bauerman, in his report published for the first time in the last annual report of the Geological Survey, also describes the rocks occurring in this pass, and it will here be necessary to give only the main facts indicating the stratigraphical relations of the beds as now understood.

Carboniferous outlier.

In ascending the Yak-in-i-kak, the first rock met with in place is about three miles due west of the Flat-head. It is a hard yellowish-grey calcareous sandstone, in some beds reddish, the bedding planes of which frequently show pitted surfaces, the pits being from a quarter of an inch to half an inch in diameter and probably representing the position of annelide burrows. It is nearly horizontal, and in continuing westward, was observed to pass in some places a little below or above the plane of the original exposures into highly calcareous sandstones. About a mile further on, grey crypto-crystalline limestone appears, in considerable exposures, and it is evident that this sandstone (which much resembles that observed at the summit of Sheep Mountain, p. 42 B) is closely associated with the limestone series. Where the limestone was first seen it is fossiliferous or at least composed of crinoidal and other organic fragments. Among specimens collected here, a *Spirifer*, a *Productus*, and a *Fenestella* have been recognised. The limestones, in very thick beds, are the rocks characterizing the cañon-like part of the valley previously described, and extend for at least two miles along the trail. These limestones are those referred to as a Carboniferous outlier by Mr. Bauerman, who states that they rest unconformably on the rocks next described to the west—an observation not repeated by the writer, but without doubt correct. At the end of Mr. Bauerman's report is given a list by Mr. Salter of fossils collected from this outlier. Meek records *Productus latissimus*, *Spirifer Keokuk*, and *Athyris subtilita* as obtained here by Gibbs.†

Cambrian rocks

Beyond the limestones, the hill-sides become covered with fragments of shales and sandstones resembling those of series C, of the eastern part of the pass, and doubtless referable to the Cambrian. About two miles further on, and four and a half from the summit, immediately to the west of the mouth of a large brook which enters the valley from the

* Journ. Am. Geog. Soc. Vol. IV. p. 382, which see also in connection with the eastern part of the pass.

† Bulletin U.S. Geol. and Geog. Survey Vol. II. p. 354, Meek gives the locality as Katlahwoke Creek. The name given by Gibbs to the stream is the same employed in this report.

north-west, the rocks are well shown. They consist of flaggy, red sandstones, and fine, grey and bluish, hard, quartzose argillites, which are marked in many places by sun-cracks and rippling, Some beds show many impressions of salt crystals, precisely like those described on a former page, though on a horizon so much lower. About a mile further on, rocks of the same series, consisting of interbedded red and bluish-grey quartzites, were observed dipping N. 15° E. < 10°, with rippled surfaces, indicating a flow in a direction of N. 33° E. Well-marked jointage-planes also traverse the beds at this place, with a course of about N. 60° E., or nearly parallel to that of the valley. At the summit, bluish-grey and greenish, close-grained quartzites, are largely developed, in association with red sandstones; the former exactly resembling the Cambrian rocks seen near Elk River bridge (p. 78 B) and probably representing the same horizon. Half a mile beyond the summit is a remarkable, broad zone of bright-red beds dipping about N. 60° W. < 40°. Beyond this point the rocks were actually observed in place near the trail at two points only, but the mountains bordering the valley are doubtless composed of the same series to where they disappear at the edge of the wide Kootanie Valley. The direction of dip appears to turn more to the west in descending the valley.

Red beds with sun-cracks and rippling.

The part of the Kootanie Valley here entered, which, between the edge of the mountains and the Kootanie River, is about eight miles in width, is generally called the Tobacco Plains. It is described on a subsequent page. A little rocky projection, about three miles west of the base of the mountains, on the trail, shows a hard, greenish, amygdaloidal diorite (?), with siliceous filling, dipping N. 30° E. < 50° This is doubtless one of the interbedded masses of the Cambrian. With this exception no rocks were observed in this part of the Tobacco Plains.

Kootanie Valley.

North Kootanie Pass.

The eastern end of the North Kootanie Pass is situated in latitude 49° 30′. The western may be stated to be at the mouth of the Wigwam River, in latitude 49° 14′ 30″, the distance from point to point, being fifty-one miles in a general bearing of N. 64° E. This pass resembles the South Kootanie Pass in the fact that on it two separate high summits must be crossed, between which lies the valley of the Flat-head. Here, however, the extreme northern end of the valley is traversed, and the region between the two summits is consequently of a considerably greater elevation than the southern. In one respect the North Kootanie Pass differs remarkably from all others in this part of the range. The South Branch of the Old Man River—its eastern approach—occupies the centre

General character of pass.

of a wide gap in the eastern range of the mountains, where the continuity of the edge of the Palæozoic rocks is interrupted for a distance of about fourteen miles. The eastern entrance of the pass is therefore not so well defined as in other cases, but from the point which may be so designated, the trail passes for about fifteen miles through a broken, though scarcely mountainous country, resembling that of the foot-hills, before it reaches the first outcrops of the older rocks which constitute the actual summit range and watershed between the Saskatchewan and Columbia systems.

Valley of the South Fork.

The point above designated as the eastern end of the pass is about three miles west of Garnett Brothers' ranch, where the wide flats, here based on a belt of soft, dark Cretaceous shales, end at the base of a line of bold, partly-wooded hills, where the trail crosses the steep valley of a small stream from the north. From this place, for about four miles westward, or up to the mouth of the Little South Fork, the valley is wide; and open prairie stretches of considerable size not only characterize the terraces and flats, but spread up over the bordering hills. Thence, for about nine miles, occasional smaller meadows occur, but the valley is more than half wooded, and trees also generally cover the adjacent slopes, the appearance of the whole being very attractive. Beyond the last of these meadows a densely wooded country is entered, and owing to fallen trees and transverse gorges, the trail is very rough, though with the expenditure of a little labour it might easily be made excellent. From the last meadow to the summit is a distance of about six miles, but as the trail reaches the higher part of the vally, the timber becomes more scattered and open in growth. The source of the stream is found in two little intercommunicating lakelets about half a mile from the

Watershed summit.

actual summit. The upper limit of the growth of trees is here nearly reached, and the hill-sides become almost bare, and are strewn with broken fragments of rock from the higher peaks. To the north, the eastern face of the watershed range, presents a fine series of limestone cliffs and crags running toward the Crow Nest Lake. The actual summit is crossed about half a mile from the lakes above referred to, at an elevation of 6,750 feet. It is a narrow defile between high rocky peaks, the trail passing over rough slopes of angular debris, almost entirely destitute of vegetation.

Timber.

In the eastern portion of North Kootanie Pass, there is a considerable quantity of good timber. So far as the valley of the main stream is concerned, the best of the timber is included in a stretch of about five miles east of the summit. It is composed of Douglas fir, spruce, and black or bull pine.

Cretaceous basin.

The Cretaceous rocks met with between the entrance to the pass and the summit range, are all much disturbed and frequently sharply flexed

with probable overturning of folds to the eastward, and possible unproved faults. To work out their relations and present a complete section would require a very careful and detailed survey. The section appended to the general map (No. 5) shows a probable outline of the structure.

The rocks consist chiefly of sandstones of varying colour and texture, interbedded with shales, and in two places coal seams were observed, as described below. Some of the shales and shaly sandstones present a peculiar dark-greenish or bluish-grey colour. Conglomerates are not extensively developed, but in three places certainly, and probably in a fourth also, ash-beds and agglomerates, like those described in greater detail on the Crow Nest Pass, were found. It is probable that a closer examination would bring to light additional outcrops of these volcanic materials which appear to characterize a definite zone at the same stage with those on the Crow Nest Pass, and as they are wide-spread, they will ultimately prove of great value in forming a reference horizon in working out the complicated flexures of this part of the region. This volcanic intercalation has already proved useful in indicating the part of the section including the coal seams. The places at which these rocks have been recognized in the North Kootanie Pass are as follows:—1. About a mile west of the little brook at the entrance of the pass, in the bank of the main stream. The volcanic material is here considerably mixed with ordinary arenaceous matter and appears to be thinning out. 2. About six miles above the mouth of the Little South Fork in the banks of the stream, and forming part of a prominent hill on the south side. The only peculiar circumstance in connection with this outcrop is the occurrence of some obscure vegetable impressions, longitudinally striated. The carbonaceous matter has been removed and replaced by crystalline calcite. 3. About three miles east of the summit. Small exposures in a dense wood. There is probably a fourth outcrop between this point and the summit. In all these places the dip is westward at varying angles, and, indeed, the greater part of the entire Cretaceous series here exposed, dips in the same general direction, leading to the belief, as above stated, that a series of overturned folds exist. The entire thickness of the volcanic material was not shown at any of these points, but it is evidently much less considerable than on the Crow Nest Pass. The rock has a greenish-grey colour and is often distinctly fragmental, sometimes showing distinct fragments of amygdaloid an inch or more in diameter. It is generally speckled with greyish, greenish and reddish points, and is more or less calcareous throughout.

Volcanic rocks.

Places at which these outcrop.

Coal seams at entrance to pass

The first outcrop met with at the eastern end of this pass, in the steep banks of a small stream crossed by the trail, is important as showing coal seams, which are with little doubt referable to the same horizon as those in the Crow Nest Pass (p 69B). These are referred to on p. 99 c. Report of Progress 1882-84. The highest part of the section at this place consists of massive sandstones, twenty feet or more in thickness, below which is a coal seam two feet ten inches thick, and though somewhat variable, capable of yielding at least one foot six inches of good coal. This is followed by about thirty feet of shales and sandstones of general dark colours, below which is a second seam of coal one foot five inches thick. The dip is S. 45° W. < 20. The coal, though thin, is of fair quality, and may prove to be of some value locally. The horizon of the seam is about 2,400 feet below the first exposure of the volcanic bed above noticed, and the series is apparently a regular ascending one between the two points. Some imperfect specimens of fossil plants were collected near the coal seam. Among these Sir J. W. Dawson has recognized *Podozamites lanceolatus* (Lindl.) and *Zamites montana* (Dn.)*

Second coal outcrop.

The second locality in which coal has been discovered in this part of the pass, is about four miles above the mouth of the Little South Fork, where the immediate banks of the stream become steep and the valley cañon-like. The exposures are on the south side of the stream and exhibit a considerable thickness of sandstones and shales, with coals and coaly layers or carbonaceous matter, at several stages. The beds are somewhat disturbed at this point, being bent into a small synclinal, and there is also a difference of appearance in different parts of individual layers, which may show that the great development of the coals at this place is a local phenomenon. No fossils were obtained, but the coals here are supposed to be at about the same horizon as those last noticed. The thickest seam shows nine feet nine inches of good coal, and is underlain by eight inches of shale, below which is a second seam fourteen inches in thickness, the whole being capable of yielding about ten feet of clean coal. Mr. Hoffmann's analysis of the coal of the nine-foot seam† shows it to contain.—

Hygroscopic water	1.93
Volatile combustible matter	23.23
Fixed carbon	57.50
Ash	17.34

Beds adjacent to coal.

The disturbance of the measures would render this an unfavourable point for the actual working of the coal, but the seam

* See Proceedings Royal Soc. of Canada, Vol. III., Sec. 4.
† Report M, p. 8.

might be traced up to some more suitable locality in the neighbouring hills. Some of the massive sandstones in this vicinity were observed to overlie the beds including the coal with apparent unconformity. This is the only place in which any appearance of unconformity has so far been met with, among the very thick Cretaceous series of the mountains, and it is probable that it may have resulted merely from local contemporaneous erosion and may here have no fundamental structural importance.

The entire section observed at this place, as measured by Mr. J. B. Tyrrell, is as follows, in descending order.— Section including coal.

	FEET.	INCHES.
1. Thick-bedded, yellowish-weathering sandstone	—	—
2. Thin-bedded sandstone	10	0
3. *Coal*	1	0
4. Sandy shale	8	0
5. Sandstone	8	0
6. Shale	0	3
7. *Coal*	9	9
8. Shale	0	8
9. *Coal*	1	2
10. Sandstone and shale	6	0
11. *Coal*	3	6
12. Sandstone and ironstone	3	0
13. *Coal*	3	5
14. Sandstone	2	0
15. Carbonaceous shale	6	0
16. Sandstone and sandy shale	30	0
17. Carbonaceous shale	2	0
18. Sandstone and ironstone	6	0
19. Coaly shale	8	0
20. Sandstone	25	0

Under this lies a bed of dark shale, then a bed of light shale, and then another bed of dark shale.

The rocks of the Cretaceous series are last seen about a mile and a half from the summit, where the older formations of the Flat-head Range appear. The junction of the two series was not seen, but it is almost certainly a faulted one, the Cretaceous being brought in by an extensive down-throw to the east. The older rocks dip nearly due west, at an average angle of about 30°, and it might be supposed that they form an overturned anticlinal, like those so frequently met with in this part of the mountains, but that this is not the case is shown by the fact that they occur in regular *ascending* order. The first of the older rocks seen is a grey, compact limestone, which is followed and overlain by a series of yellowish-grey, flaggy, more or less dolomitic limestones, at least 200 feet in thickness. These are followed by sandstones for the most part red, which show ripple-marks, sun- Fault east of summit. Rocks overlying limestone series.

cracks and pseudomorphous impressions of salt crystals. Over these lies a bed of contemporaneous trap, about 100 feet in thickness, which can be traced running up the slopes of the mountains on both sides of the valley, forming bold cliffs. This is followed, in ascending order, by a second series of red beds, reproducing the characters of the first, but about 600 feet in thickness, above which is a series of flaggy and shaly dolomitic sandstones, weathering to brown and fawn colour, and showing in some layers impressions of salt crystals. Drusy cavities were observed to occur in a few places, lined by small dolomite crystals, with a few of baryte and copper pyrites. The thickness of these rocks is again about 600 feet. They are followed by a similar volume of red beds, almost entirely sandstone, which frequently form rather thick layers. These continue to the actual watershed, and are the highest beds seen at the summit of the pass, where another extensive fault causes them to abut on the older limestones. Near the fault, these sandstones have become locally changed into hard quartzites of a purplish-grey colour, in which the iron appears to have become concentrated in certain layers while the intervening laminæ have become almost colorless.

Summit fault.

Comparison with Triassic rocks elsewhere

The rocks here displayed evidently represent those from the summit of the great limestone series, to the top of the section as represented in the South Kootanie Pass, or from series D, upward. They may be summarized as below to facilitate comparison with the section on page 39 B. It will be observed that while the general conditions of deposit indicated by the red and fawn-colored beds are similar in both sections, the thickness and arrangement is somewhat different in the two localities, the most important change being the existence here of a considerable thickness of red beds below the trappean flow. There is every reason to believe that the trap occurring above the great limestone series represents a single period of eruption, as its continuity is unbroken for many miles, where good sections enable it to be followed, near the South Kootanie Pass. This being so, it would appear that the conditions producing the red sandstones set in somewhat earlier to the north; and further, from its association, that the trappean eruption should be classed rather as a portion of the red series than as a separate member between this and the limestones.

General section

The entire section is as follows in descending order.—

	FEET.
1. Quartzites and red sandstones	610
2. Fawn-coloured beds (about)	600
3. Red sandstones, shales, etc. "	600
4. Amygdaloidal diorite (?)	100
4. Red sandstones, shales, etc	100
6. Yellowish, dolomitic, flaggy limestone, 200 or more	200
	2,210

Little South Fork.

Before continuing the description of the pass west of the main summit, a few words may be added respecting the Little South Fork. This stream, the most important tributary of the South Fork, joins it four miles from the entrance of the pass. The Little South Fork is nearly equal to the main stream in volume and is formed, at a distance of about six miles above its mouth, by the junction of two rapid streams, each about thirty feet wide by six inches deep, fed by a number of smaller brooks which issue from rugged valleys in the limestone mountains. A well-beaten Indian trail runs up the western branch, and probably passes over the range to the head-waters of the Flat-head, though it was followed about two miles only above the forks referred to. The valley of the Little South Fork is wide, with many patches of prairie, and some of the adjacent hill-slopes have been almost completely denuded of timber by fire. The Cretaceous rocks exposed along the stream are generally sandstones and present no features of special interest, though a band of dark shales and shaly sandstones, several hundred feet in thickness, occurs near the mouth. The strike is very regular in the lower part of the valley, averaging N. 50° W. with dips at an angle of about 30° south-westward. A specimen of *Pinna Lakesii* was found in sandstone on the west side of the stream, and with the exception of some fragments of Belemnites, is the only fossil mollusc obtained in the Cretaceous rocks of this vicinity.

Character of valley.

Rocks.

Gravel banks nearly one hundred feet high, occur in some places on the stream, and these, toward the base, are hardened by calcareous matter into a species of conglomerate. No overlap of the Cretaceous rocks on the older beds of the mountains was observed, but it is probable that the irregular edge of these rocks to the south is partly of this character and in part defined by faults. At this point the end is found of the important trough (Crow Nest trough) of Cretaceous rocks which runs northward behind the first range of the mountains for ninety-five miles.

North Kootanie Pass (Continued.)

From the east or main summit on the North Kootanie Pass, the trail descends rapidly to the south-west by the valley of a small brook, which in three miles joins the Flat-head. It then follows the north bank of the Flat-head, crossing four considerable and several smaller brooks, and in fourteen miles further reaches the source of the river and the western summit. The valley is generally wooded, but in its lower part several little meadows occur, and near the western summit the

Head-waters of Flat-head.

woods become open in consequence of the altitude attained, and little alpine meadows are frequent. The ascent to the western summit is quite gradual, but on attaining the crest, it is found to be a narrow ridge, broken off very abruptly toward the south-west. The summit is partly open and remnants of snow drifts may be found in sheltered hollows throughout the summer. There is good pasturage for a few animals here in July and August.

The height of this summit, where crossed by the trail is 6,850 feet, but the ridge might be passed at a lower level further to the south-east. The lowest part of the trail between the western and eastern summits is quite near the latter, and has an altitude of 4,925 feet.

View from western summit.

From the western summit, the whole basin which constitutes the head of the Flat-head Valley is well seen. The region between this and the eastern or watershed range, and northward toward the Crow Nest Pass and the Elk River, is occupied by rounded hills, which are arranged more or less definitely in linear series, forming ridges with general north and south trends. The slopes are not usually abrupt, and both the hills and intervening valleys are almost everywhere densely wooded and show but little burnt wood or wind-fall. There must be a very considerable quantity of good timber in this region, chiefly spruce. The summits of the hills are generally about equal in height, their average elevation being a little over 6,500 feet.

The view from the west summit, looking down the gorge of the Wigwam River, must be very fine, but was much obscured by smoke at the time of my visit. To the south and south-east is a mass of high and wild limestone peaks forming the northern part of the Macdonald Range.

Wigwam River.

The descent from this summit to the head-waters of the Wigwam River is at first extremely steep and rocky, and the trail passes in the valley through dense woods for nearly four miles before the first little opening in which pasturage can be obtained is reached. Three miles further on, the main stream of the Wigwam enters the valley. It rises, according to the Boundary Commission maps, quite near to the western summit of the South Kootanie Pass, a few miles south of the 49th parallel. Opposite the mouth of the main river is a high mountain, crested toward the summit by limestone cliffs [illegible] North Bluff by Blackiston. West of this point the valley opens more widely, though the river still runs in a [illegible] gorge in its centre. The trail here leaves [illegible] nearly three miles over a high ston[illegible]ch lie a number of large, detached, angular [illegible]. It [illegible] descends by several steep zig-zags to a lower terrace, which occupies the angle between the Wigwam and Elk rivers. Near the mouth of the

Wigwam, the Elk may probably be forded at low water, but the trail now generally followed runs up the Elk River, on the east side, for about three miles, to the bridge which has been thrown across at the upper end of the cañon. (See p. 78 B.) This part of the trail is rough, following a broken slope above the edge of the chasm, several hundred feet in depth and with almost vertical sides, in which the Elk here flows.

The valley of the Wigwam and adjacent hills and slopes are generally well wooded, particularly on the south side of the river, and as this pass has as yet scarcely been used, save by Indians, very little destruction from forest fires has occurred.

Rocks between east and west summits.

No detailed section can be given of the rocks between the east and west summits on the North Kootanie Pass, as the country is all densely wooded and exposures are few. The general structure is, however, sufficiently simple, being that of a synclinal of Cretaceous rocks, of which the east side dips westward, while the opposite side dips to the north-east. The rocky notch by which the trail crosses the eastern range is evidently a break produced by an extensive fault, with down-throw to the eastward. This has already been referred to (p. 60 B) as the summit fault, and by it the red sandstones and associated rocks of the mountains on the east side of the notch, and stream beyond it, are brought in contact with the massive Devono-Carboniferous limestones on the west. The throw of the fault must be at least 1,500 feet, and is probably much greater. It runs about N. 40° E. through the notch, but appears to turn to nearly due north on the east side of the summit. A number of fossils were collected from the limestones near the summit, among which a preliminary examination shows the following forms.—

Faults.

Dendropora.	*Strophodonta*, Sp.
Aulopora.	*Spirifera Maia.*
Syringopora (?).	*Atrypa reticularis.*
Striatopora.	*Atrypa spinosa* (?).
Zaphrentis.	*Retzia Verneuiliana.*
Productus Hallanus (?),	

There are probably several other important faults in this neighbourhood, one of which must run between the western base of the the summit range and the series of narrow ridges of Cretaceous rocks which lies south of the Flat-head, where it is first reached by the trail. This is rendered evident by the fact, that to the north of the river the Cretaceous sandstones rest directly on the limestones, while they are here brought in contact with the much higher red rocks, and though the Cretaceous and limestone series must be regarded as unconform-

able, it is improbable, from analogy with other parts of the district, that they lie upon two such different portions of the older series within so short a distance. The ridges last referred to run about north-east and south-west, and appear to form a system isolated by faults from those characterizing this basin generally.

Junction of Cretaceous and limestone series.

At the summit notch, the limestones dip northward at rather low angles. They form the mountains on the north side of the trail and Flat-head River, to the second large brook which is crossed (a stream of about ten feet by six inches), dipping, where last seen, nearly west, and having a total width at right angles to the strike of about five miles. The gravel in the bed of the brook just referred to, is about half Cretaceous sandstone, the remainder being either limestone or pale calcareous sandstone of the kind subsequently mentioned as forming the upper layers of the limestone series on the Crow Nest Pass. It is probable that the Cretaceous here rests directly on the calcareous sandstones, as occurs a few miles northward at the upper Crow Nest Lake.

Cretaceous basin.

The main Cretaceous synclinal above alluded to, from this point, where its eastern range is reached, to the crest of the western summit, is almost nine miles wide, on the line of the trail. It may be complicated by minor flexures. It is conjecturally terminated southward on the map, according to the observed general strikes of the rocks, though the region here lying between this and the South Kootanie Pass was not examined. The ascent to the western summit is made nearly on the slope of the beds which dip north-eastward at angles not exceeding twenty degrees, and consist, so far as seen, of sandstone of the usual character, with some conglomerate. These are well exposed along the crest and on the escarpment of the summit ridge on the Wigwam River side, where they dip in a similar direction at an angle of about forty degrees. A short distance down the escarpment, the sandstones become rather shaly and one or more thin coal seams occur. The Cretaceous series extends on the trail for about two miles beyond the summit and where last seen was nearly vertical. It would appear that the thickness of the Cretaceous series, from the rocks at the summit of the ridge downward is at least 7,000 feet, though the section is not continuous.

Limestone ranges near Wigwam.

The rugged mountains already mentioned as lying to the south and south-east of the summit ridge, appear to be entirely or chiefly composed of limestone, the Cretaceous rocks of the summit ridge terminating among them in the form of a bay. The range to the south shows from a distance a sharp anticlinal fold as its dominant structure. The precise south-western edge of the Cretaceous was not defined on the Wigwam, the rocks being concealed for some distance north-east from the first range through which the valley cuts. This and a second range, beyond

it, are composed of limestone of the usual character. Between these mountain masses, on the north-west side of the stream, is a small area of greenish Cambrian quartzites. The lower hills about the mouth of the Wigwam are entirely composed of Cambrian rocks.

Cambrian rocks on the Elk.

About the mouth of the Wigwam, and for a mile and a half northward along the Elk, the Cambrian rocks are extremely disturbed and shattered, and from the number of jointage-planes cutting them in all directions, weather into steep, bare, rubbly banks, which are often nearly vertical. These assume pale tints where clayey matter has coated the joints, but in other places are bright-red from a coating of iron oxide. At the point last mentioned it is probable that a great fault or line of disturbance and comminution crosses the Elk very obliquely, with a course of about N. 10° W., as after passing that line, the massive Cambrian quartzites and slaty shales are found nearly undisturbed, with light undulating dips, weathering out in block-shaped masses only, and forming the vertical-sided cañon which is crossed by the bridge (p. 78 B).

Vegetation.

The character of the change found to occur in the vegetation, and particularly in the timber, in crossing from the eastern to the western side of the Rocky Mountain range, having previously been noted in connection with the South Kootanie Pass, need not be repeated here. It may, however, be mentioned that the Douglas fir occurs in the valley of the South Fork, on the east slope, and near the mouth of the Wigwam on the west side. It is never an alpine tree in this region. The trees found near both summits are chiefly *Abies subalpina*, *Picea Engelmanni* and *Pinus albicaulis*. The vegetation about both summits is, as might be expected from the altitude, quite alpine in character. The little meadows on the west summit, still partly covered by patches of snow, were gay with the bright yellow flowers of *Erythronium minor* on the 26th of July. On the east side of the eastern summit, a hill-side was observed a few days later completely covered with the beautiful *Rhododendron albiflorum*.

Crow Nest Pass.

General character of the pass.

This pass is that which has of late years been most used as a means of communication between the Great Plains and the Kootanie country. A practicable trail has been cut out, and bridges built over several of the larger streams, and considerable numbers of horses and cattle have been driven east by it. The trail, as now laid out, does not correspond with any well-known Indian route, and though possessing some advantages over the North Kootanie Pass, is by no means so direct. It follows up the Middle Fork of the Old Man, or Crow Nest River to its

source, beyond the Crow Nest Lake, crossing a low summit to the headwaters of a branch of Michel Creek, a tributary of the Elk. Another summit is crossed between Michel Creek and Coal Creek, also a tributary of the Elk. Coal Creek is then followed down to the Elk. After reaching the Elk, the trail runs along the east bank of the river to the cañon where a bridge has been thrown across. The wide Kootanie valley is finally entered at a point only a few miles north of the western end of the North Kootanie Pass.

Valley of the Middle Fork.

The eastern end of this pass is well marked by the Livingstone or outer limestone ranges of the mountains, cut through by the Middle Fork in a deep, narrow valley. This is usually designated "The Gap." Within the Livingstone Range, the valley of the Middle Fork is wide and open as far as the lake, or for about eight miles. This part of the valley is characterized by wide, grassy terraces, and many of the hills bounding the valleys to the north are open and grassed to their very summits. Those on the south, are, however, generally wooded, and north of the valley, the whole country becomes either densely wooded or covered with burnt woods and wind-fall, after the first two or three miles. It was my intention in 1883 to strike northward from this part of the valley to the North Fork, but after losing an entire day in making a very few miles, and seriously injuring one of our horses, this was abandoned. The hills to the north and south of the valley are in reality the ends of series of nearly parallel ridges, presenting remarkable uniformity and conforming in direction with the strike of the rocks.

The valley of the Middle Fork, between the Livingstone Range and the lake, like all those in the eastern part of the mountains, where extensive meadows border the streams, is extremely attractive in appearance. The Crow's Nest Mountain, standing alone amid lower hills, three miles north of the trail, and the high limestone peaks which crowd upon the lake on both sides, present fine rugged outlines.

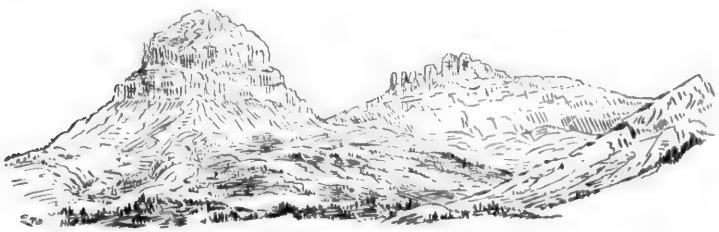


FIG. 2. THE CROW'S NEST. FROM A HIGH RIDGE, ABOUT THREE MILES EAST.

Crow's Nest.

The height of the Crow's Nest was approximately determined as 7,830 feet above the sea, and though much less than that of other peaks in this part of the range, its nearly conical outline and isolated position, render it a prominent object as viewed from the plains far out to the south-east. On one of the maps accompanying Captain Palliser's preliminary report* it is named *Loge des Corbeaux*. Its Cree name, of which the others are translations, is *Kah-ka-ĭoo-wut-tshis-tun*. Viewed from the pass or neighbouring ridges, its summit is seen to be entirely composed of the great Devonio-Carboniferous limestone series in a nearly horizontal attitude. Its apex is bluntly conical and is bordered by almost vertical cliffs. To the north, a lower spur attaches to it, crested by several remarkable chimney-like columns of the same limestone. This mountain in its structure and general appearance much resembles Chief Mountain, previously described. The highest peak on the south side of the Crow Nest Lake has an altitude of 8,600 feet.

Crow Nest Cretaceous trough.

Geologically considered, the eastern part of the Crow Nest Pass affords a section of the great eastern Cretaceous trough† parallel to and about ten miles north of that of the North Kootanie Pass. The trough is here, however, about seven miles only in width, and its eastern margin is strictly defined by the limestone outcrop forming the Livingstone Range. The structure met with in this pass is represented in a generalized way on section No. 4. Probably as a consequence of the protection afforded by the massive limestone rocks of the Livingstone Range, the Cretaceous rocks of this part of the trough are much more regular and undisturbed than on the North Kootanie Pass. Just where the Middle Fork breaks through the Livingstone Range, the strike of the limestones and Cretaceous rocks changes from nearly north, on the north side of The Gap, to south-east on the south side. It is probable that this change is connected with a line of fracture or weakness which has been followed by the river, though there is no reason to believe that actual faulting occurs to any considerable extent.

Livingstone Range.

The precise character of the junction of the Cretaceous of the foot-hills with the limestone of the east base of the Livingstone Range at this place, is doubtful, the rocks being much disturbed, and varying within a short distance from vertical to nearly horizontal. Immediately north of The Gap, however, a mass of Cretaceous sandstones is seen on the flank of the limestone range, dipping at a low angle toward it, *i.e.* westward. The limestones also dip westward at varying angles, averaging

* Papers relative to the Exploration by Captain Palliser, etc., 1859.

† This Cretaceous area may be designated the Crow Nest trough, to distinguish it from others in the mountains. It was first observed by me in this pass in 1881. See Prelim. Note on Geology of Bow and Belly Rivers District, 1882.

about forty degrees, but in some places becoming nearly vertical. The impression at first conveyed is that the limestones are brought up by an extensive fault running along the base of the range parallel to its direction, but the proved existence in a number of places of overturned folds, and the resemblance of the limestone ridge here to an anticlinal of this character, leads to the belief that it is an overturned anticlinal, combined with a fault with down-throw to the eastward. On comparing the parallel portion of the North Kootanie section, it even appears probable that the first large overturned Cretaceous anticlinal on it may be the southern continuation of the same fold, which has here become so considerable as to bring the limestone to the surface.

Cretaceous, east of Livingstone Range.

Outside the Livingstone Range, the Cretaceous rocks met with on the trail eastward, to the wide, crumpled belt of dark shales which runs through from the South Fork (see map accompanying Report of Progress, 1882-84), are chiefly sandstones, generally greenish-grey in colour, and sometimes shaly. In some beds, the sandstones are brown-weathering, and in others, pale grey, weathering to reddish tints. These rocks all dip very regularly to the south-west, at angles of 30° and upward. The valley crosses them very obliquely, and no extensive beds of dark shales were observed. The sandstones are sometimes so hard that they might almost be described as quartzites. On the east side of a large brook which joins from the north, less than a mile from the edge of the limestone, rather massive beds of conglomerate occur, with westward dip at an angle of about 10°. The pebbles are all well rounded, and consist largely of chert from the limestones, together with quartzites and quartzose-schists like those of the Cambrian, among which a fine-grained, flesh-red quartzite is prominent. There are also some pebbles of a grey, slightly porphyritic crystalline rock, of which the origin is uncertain. On the west side of the brook, at a short distance, are thick beds of very hard, speckled sandstone, vertical, with a strike of S. 20° E.

The Gap.

In The Gap, the valley becomes quite narrow, but widens again immediately the limestones are passed. The breadth of the limestone axis on the trail, which crosses it nearly at right angles, is about a mile and a quarter. At its western edge, the rocks dip with great regularity westward, and are overlain by the Cretaceous sandstones dipping in the same direction and at a similar angle. Thence, for three miles, the only rocks seen were sandstones, which in one place were observed to become conglomeritic, and in another to be composed largely of whitish felspar in sub-angular grains. The section is not continuous, and could only be made so by including in an accurate survey the whole of the neighbouring hills; but the series appears to be a regular, ascending one, and if not complicated by unknown flexures

Rocks of Crow Nest Cretaceous trough.

or faults, must be about 7,000 feet in thickness.* At this point the trail is crossed by a brook from the north, in which rolled fragments of coal were observed, and at a distance of about half a mile to the north, the seams from which these fragments had been derived were found in the banks. There are three seams in all, included in an exposed thickness of about forty feet of brownish, greenish and dark-grey shaly sandstones and shales, the whole being overlain by massive grey sandstones. The highest seam is two feet thick, and is separated by about twelve feet of shales and shaly sandstones from the next, which is two feet ten inches thick, and about fifteen feet below it is a third, one foot five inches thick. The dip is here S. 85° W. $< 30°$. The coal is a bituminous one, and yields a firm coke. An analysis by Mr. Hoffmann shows it to contain only 1·82 per cent. of water, and 51·22 of fixed carbon. It yielded, however, 22·41 per cent. of ash. (see p. 6 M.)

Coal seams.

The appearance of the section including these coals is so close to that previously noticed as occurring at the entrance to the North Kootanie Pass, that I believe the horizons represented to be identical.

For a distance of a mile and a third from these exposures, grey sandstones, with occasional layers of cherty conglomerate and greenish-grey shaly sandstones, are exposed at intervals. It is very probable that there is a considerable proportion of shales, but if so, these, owing to their soft character, are for the most part concealed.

Beds overlying the coals.

At this point the base of a great series of rocks of volcanic origin crosses the valley, and it was here, in 1881, that materials of this character were first observed in the Cretaceous of the region.† These rocks are chiefly, if not entirely, fragmental, consisting of agglomerates of varying coarseness, which are frequently so fine as to be designated volcanic ash rocks. They are for the most part greyish-green or purplish in colour, and toward the base, in some places, weather easily, forming rounded, crumbling masses. There are also reddish and grey, fine, shaly layers here and there, and small segregations of copper pyrites were seen forming scattered granules in some of the agglomerates. They are generally, if not in all cases, distinctly calcareous, effervescing freely on the application of an acid, and nepheline appears to be present in addition to felspar.

Volcanic rocks.

These rocks, owing to their greater homogeneity and resistance to weathering, form a high, straight strike-ridge, running for a number of miles to the north and south. Where they cross the stream, its immediate valley becomes narrow and steep sided.

* This is identical with the thickness—independently estimated—from the base of the formation to the horizon at which thin coal seams (probably the same with these) occur on the North Kootanie Pass. p. 64 B.

† It may be observed in this connection that Prof. J. J. Stephenson notes the occurrence of volcanic rocks and volcanic ash in the lower portion of the Cretaceous in Colorado. U. S. Geol. Surv. West of 100 Merid., 1875, Vol. III., p. 500.

Thickness of strata.

The thickness of the sedimentary beds intervening between the coal-bearing horizon and the volcanic rocks is here apparently considerably greater than where previously estimated at the entrance to the North Kootanie Pass, being about 3,350 feet. The thickness of the agglomerate and ash beds is about 2,200 feet, which is so much in excess of that elsewhere observed, as to lead to the belief that this place is not far remote from the centre of eruption which has produced this intercalation.

Probable faults

If the order of succession observed on the North-west Branch of the North Fork obtains here, a considerable thickness of shales should overlie the agglomerates. These, however, were not observed, and if present, must occupy a small breadth only. This fact, taken in connection with the circumstance, established on other grounds, that at the east base of Crow's Nest Mountain there is almost certainly a fault, with extensive down-throw to the east, which might be expected to cross the valley here, leads to the belief that the rocks met with west of the volcanic series, to the end of the lake, probably represent those underlying the coal horizon. So far as the exposures enable an opinion to be formed, the rocks are sandstones of similar character to those previously seen, with similar westward dips. The distance from the summit of the volcanic series to the last sandstone exposures at the lake, is three miles, and if regular and not disturbed by further faults, the thickness of the beds should be about 9,800 feet. The junction between these rocks and the limestone series, next met with, is evidently a faulted one.

Crow Nest Lake

The Crow Nest Lake, with an elevation of 4,250 feet above the sea, is about two miles in length, with an extreme width of a little more than half a mile. It lies in a deep, transverse valley which here cuts through the central limestone range of the mountains, and which enables the Middle Fork of the Old Man to draw a portion of its water from the country to the west of this range. The mountains rise in bold cliffs and scarps on both sides of the lake, rendering this, one of the most picturesque spots in the mountains, which is easy to reach. The old trail, turning to the north at the east or lower end of the lake, ran westward, nearly parallel to it, in a narrow, dry valley. A better track has lately, however, been found along the north shore of the lake itself.

Remarkable spring.

Half way up the lake, also on the north side, is a very remarkable spring which constitutes the chief feeder of the lake, and may be designated the source of the Middle Branch, or Crow Nest River. The spring issues from a large, overhung grotto in the face of the limestone cliff, the water welling up from the interior of the grotto, and filling a deep, clear pool at its mouth. It then falls about twenty feet to form a large, rapid brook, which, after a course of a few yards, loses itself in the

lake. The water has worked its way through the limestone along a nearly horizontal crack or jointage-plane, and is probably supplied by the drainage of the valley to the north of the mountains already referred to.

The immediate border of the lake is low at the west end, but a steep hill rises at no great distance back. At the base of this the valley bifurcates, the south-western branch conveying a stream of some size to the lake, the western, occupied by sloughs and woods, is followed by the trail, which, in a little over a quarter of a mile, reaches the narrow extremity of a second lake, which is between three-quarters of a mile and a mile in length. No water was observed to flow between the lakes, but it is evident that that last-described empties into the Crow Nest Lake at seasons of flood. Running northward from the upper lake is a flat-bottomed valley, in which, though not connected with the lake, a small stream rises, and flowing to the north and then north-westward doubtless eventually joins Michel Creek. The actual watershed between the Old Man and Elk River systems may therefore be said to be at the level of the upper lake, or 4,400 feet. The trail, however, at the west end of the upper lake, turns southward, following a small stream which enters the lake, then south-westward, crossing several rills which flow toward the stream previously described as falling into Crow Nest Lake, and eventually crosses the watershed at a point three and a half miles south-west of the upper lake, at an elevation of 4,830 feet. The actual height of land is therefore lower on this pass than on any other known south of the Yellow Head Pass.

Upper Lake.

Watershed region.

Rocks of the limestone series extend from the lower end of Crow Nest Lake to the west end of the upper lake, with a width of three and a half miles. The limestones constitute an almost uninterrupted section along the north side of Crow Nest Lake, and were ascertained to have an apparent thickness of 9,610 feet, with regular dip at an angle of about 30 degrees between S.W. and W. There is no appearance of any repetition by faulting in this section, and while the structure of the mountains elsewhere would suggest the probable existence of compressed and overturned folds, no distinct evidence of such folding could be found here. Compared with the thickness of limestone elsewere developed in the mountain region, however, that in this section is so great, that the thickness here may probably be actually due to repetition by folding, as indicated hypothetically on one of the sections attached to the map. The entire section, from west to east, in descending order, is as follows :—

Limestones on Crow Nest Lake

	FEET.
1. Cherty crinoidal limestone	1,680
2. Compact, slightly crinoidal limestone	1,480
3. White, crinoidal limestone	1,710
4. Brownish-weathering, cherty limestone	1,040
5. Massive grey limestone	1,220
6. Grey and blackish limestone	460
7. Fine-grained, grey limestone	1,420
8. Cherty grey limestone	600
	9,610

Probable constitution of rock series.

On the basis of the hypothetical folding indicated on the general section (*i.e.*, two compressed and overturned anticlinals, with an intervening synclinal) the actual rock-series exposed here would be as follows.—

	FEET.
1. Calcareous sandstones (described below), at least	300
2. Cherty crinoidal limestone	1,680
3. More compact and less crinoidal limestones	1,595
	3,575

Fossils.

Fossils, which were obtained at several different points on the line of the measured section, favor the view of a repetition of the beds, as they offered no distinct evidence of such a change in horizon as might be expected to occur between different parts of so great a thickness of strata. The principal fossils represented, most of which are characteristic Devonian forms, are included in the following list.—

Stromatopora, sp.
Crinoidal fragments.
Polypora stragula ?
Syringopora, allied to *S. perelegans.*
Diphyphyllum, sp.
Zaphrentis, sp.
Chonetes mucronata.
Productus sp.
Orthis, like *O. Tulliensis.*
Rhynchonella castanea.
Atrypa reticularis.
Spirifera, sp.
Cyrtina Davidsoni.
Platyceras (two or more species).
Euomphalus, sp.

Overlying No. 1 of the first section, on the west side of the valley, at the upper lake, are hard, whitish, more or less calcareous sandstones, which in some layers show cherty concretions, and are evidently a conformable upper portion of the Palæozoic limestone series. Similar sandstones were seen in the same position in many other parts of the mountains, and in some places have yielded Carboniferous fossils. These sandstones also constitute the ridge on the west side of the valley at the head of the upper lake, but in the next ridge, separated from this by a narrow valley only, sandstones outcrop, which evidently belong to the Cretaceous series, the line of junction of the two formations following the narrow valley between these ridges. Thence to the summit crossed by the trail, though at a considerable elevation and in the heart of the mountains, the country is characterized by low, broken hills and ridges, composed of or deeply covered by drift material resembling boulder-clay, and cut up by little ravines. Terraces are distinctly traceable to levels about 500 feet above that of the summit, and some of the ridges are evidently morainic in origin. This peculiar tract is shut in on all sides but the north-west by high and rugged mountains. It is thickly strewn with angular *débris* of Cretaceous sandstones, and its occurrence doubtless depends on the softer character of the rocks of that series. To the southward are two valleys. One, which holds a small tributary of the stream flowing to Crow Nest Lake, ends in a rather extensive snow-field; the other, further to the west, and wide, though not low, probably leads along the western foot of the main limestone range to the Flat-head Valley. The woods have been almost entirely removed by fire from the broken country about the summit.

Calcareous sandstones.

Base of Cretaceous series

Broken, drift-covered country

On descending from the summit, westward, by a rather narrow valley, the country becomes distinctly more humid in character, and the trail passes for several miles through fine woods. A mile and three quarters from the summit, it reaches the bank of the East Branch of Michel Creek, a large, rapid stream issuing from a wide valley running off to the south-east. This is followed for about a mile, when it is crossed by a ford. The track then runs over a wooded point and along some terraces, till, in three quarters of a mile, it reaches the east side of the West Branch of Michel Creek, a stream forty feet wide by ten inches deep. This is crossed by a bridge, and the steep hill-side forming the left bank of this stream is followed by a rough, difficult trail, till a descent is again made to the water-level at the mouth of Marten Brook, which joins from the north.

Descent to the westward.

From the summit to this point, the surrounding country is a mass of low, steep-sided, Cretaceous mountains, which seldom rise 2,000 feet, and often only 1,000 feet above the level of the stream. The

Cretaceous hills

valleys, which intersect them in all directions, are narrow and rugged. These hills, and those further west, to the Elk River, are an extension of the Cretaceous area which is overlooked from the western summit of the North Kootanie Pass (p. 62 B). The hill-sides are thickly covered with reddish boulder-clay, which is packed with stones of proximately local origin, and does not include limestone fragments. The same material forms terraces in lower places along the valleys, but at no very great elevation above the streams. With the exception of very restricted patches of living wood in the valleys or on remote slopes, the surface bristles with standing dead trees or is covered with fallen burnt logs.

Western summit and Coal Creek.

Crossing Marten Brook, which is a small stream in a narrow rocky valley, the trail ascends rapidly, following a little stream from the level of the brook (4,800 feet) to that of the western summit on the Crow Nest Pass, with an elevation of 5,500 feet. In less than two miles a descent is then made by the valley of Coal Creek, of more than 1,100 feet, after which the stream has a less rapid descent, and in eight miles falls into Elk River, which at this point has an elevation of 2,200 feet.

The second or western summit on this pass, though actually higher than the main watershed, only separates the head waters of Michel and Coal creeks, both tributaries of the Elk. The trail crosses to avoid the necessary detour and thick timber which would be met with in following Michel Creek north-westward from the point where it is first reached, to the Elk. In taking this direct route, the trail reaches at the summit a height only a few hundred feet inferior to that of the surrounding Cretaceous hills. The appearance of the whole country from Marten Brook to the Elk, and in the wide valley of the latter, is desolate in the extreme, the forests with which it has been covered having been almost entirely destroyed by repeated fires, which have swept over the region since the Crow Nest Pass has become a travelled route. The valley of Coal Creek is deeply cut among the Cretaceous hills of monotonous and plateau-like outline, and no wide view of the country is obtained till the Elk is reached.

Calcareous sandstones.

The geological features of this part of the pass are sufficiently simple. Near the point at which the East Branch of the Michel Creek is first reached, Cretaceous sandstones occur, but are immediately followed by whitish calcareous sandstones, underlying the last and representing those before described as attaching to the limestone series. These occur on both sides of the stream where it is crossed, and dip eastward at an angle of 35°. The calcareous sandstones probably occupy a small area only, as they were not again seen, and the fragments generally strewing the surface are so uniformly of the brownish Cretaceous sandstones and conglomerates as to indicate, even in the absence of expos-

ures, that these characterize almost the entire region. As, for three miles further, no exposures were met with in the valley of the West Branch of Michel Creek, it is uncertain whether these calcareous sandstones are cut off by a fault to the west, or form the salient angle of a fold.

Coal seams on Marten Brook.

Before reaching Marten Brook a low anticlinal of Cretaceous rocks similar to those above alluded to, is crossed, and on Marten Brook the strata have a westward dip at angles of 25 to 30 degrees. Marten Brook nearly follows the strike, and is interesting on account of the occurrence of coal on it. In a section at the trail-crossing, on the west side, is a seam showing a thickness of at least three and possibly four feet of very fair coal, with one stony parting of about two inches. Just above the crossing-place three thin seams are seen, one with nearly two feet of coal, the others less than a foot in thickness, and all irregular. A specimen from this seam, examined by Mr. Hoffmann, was found to yield a [illegible]. It contained 2·12 per cent. of water, 43·48 per cent. of carbon, and 27·48 of ash. The great proportion of ash being, however, partly due to adherent earthy matter in jointage-planes. (See p. 9 M.) A mile above the crossing are four seams, included in about a hundred feet of measures, all less than a foot in thickness, and similarly irregular. The beds associated with the coals are massive or shaly sandstones which often weather to yellowish or reddish tints, with grey and blackish shales and cherty conglomerates. A number of well-preserved fossil plants, characteristic of the Kootanie group, were collected here, including the following species.—*

Fossil plants.

Dicksonia, Sp.
Asplenium Martinianum, Dn.
Dionites borealis, Dn.
Podozamites lanceolatus, Lindl.
Zamites montana, Dn.
Zamites acutipennis, Heer.
Sphenozamites, sp.
Salisburia Siberica, Heer.
Salisburia lepida, Heer.
Baiera longifolia, Heer.
Pinus Suskwaensis, Dn.

Beds overlying coals.

Between Marten Brook and the west summit, the dips continue westward at angles of 20 to 25 degrees, and fully 1,500 feet in thickness of beds must here overlie the coals. The rocks, so far as exposed, con-

* Trans. Royal Soc. Canada, Vol. III., Sec. IV., p. 8.

sist of sandstones and conglomerates of the usual character. At the summit some very massive conglomerates were observed. On descending westward, the beds dip nearly at the angle of the slope, but afterwards turn northward, the strike then nearly coinciding with the direction of the valley, and the outcrops of the sandstone beds showing in the adjacent hills as horizontal or gently undulating lines. Five and a half miles west of Marten Brook, on Coal Creek, coal seams of a few inches in thickness occur, associated with beds precisely like those of Marten Brook, and holding fossil plants of the same species, among which the following forms have been recognized.—

Coal Creek.

Fossil plants.

Asplenium Dicksonianum, Heer.
Podozamites lanceolatus, Lindl.
Salisburia lepida, Dn.
Pinus Suskwaensis, Dn.
Sequoia Smittiana, Heer.

Coal-bearing horizon.

The horizon is probably identical, and the general effect of the section as shown on the trail, from Marten Brook to this point, is that of a wide, low synclinal. There is also every reason to believe that the coal-bearing horizon here met with, is the same with that described east of the Crow Nest Lake, and though the exposures are few near the main or watershed summit, it is not improbable that the same horizon may recur there, occupying the trough of a synclinal midway between the upper lake and the crossing of the East Branch of Michel Creek.

Near the mouth of Coal Creek, high eastward dips were observed, but these appear to be local, as the general aspect of the outcrops in the higher hills is nearly horizontal, with a slight though distinct tendency to dip away eastward from the valley of the Elk. In this part of the Elk Valley small exposures of soft crumbling sandstones were seen, but the valley is generally floored by terraced drift deposits.

Elk River.

At this point, the Elk is a swift, clear, blue, mountain river, about 300 feet wide. Its valley has not been examined, northward, for a distance of twenty-eight miles, but the gravel forming its bed here consists of Cretaceous sandstones and conglomerates, with much limestone, and there is no reason to believe that any rocks underlying the limestones come to the surface along this part of its course. Nearly opposite the mouth of Coal Creek, a stream which is evidently of considerable size and is known as Lizard Creek, joins the Elk from the opposite side. The valley of this stream is wide and straight, and is bordered by high mountains, particularly on the south side. From the high terrace on the east side of the Elk, it can be seen for about six

miles, running nearly due west, in which direction it appears to terminate among high, densely-wooded mountains. It would afford a direct route for the continuation of the Crow Nest Pass trail to the mouth of Bull River, on the Kootanie, and avoid the present detour to the south; but apart from the probably rough character of the intervening mountains, it is rendered impracticable by the impossibility of fording the Elk except at very low stages of the water. Lizard Creek.

This part of the Elk Valley runs nearly north-and-south in the heart of the Rocky Mountains. Following along the left or east bank of the river, the trail turns southward, and continues in that direction for eleven miles. The valley is from a mile to a mile and a half wide between the bases of the hills, and is occupied by terraces which are sandy and much cut up by denudation. The whole region, with the exception of some sheltered valleys along the west side, has been burnt over. The mountains on the east side rise about 2,000 feet above the river, with uniform outlines, and are all composed of Cretaceous rocks. Rocks of the same series are seen in the valley in a few places, and the depression appears to follow the strike of a belt of soft, shaly beds and sandstones, which must be low down in the Cretaceous. On the west side, the mountains are higher and more rugged in outline, and constitute the continuation of those mentioned as occurring to the south of Lizard Creek. These may be called the Lizard Mountains, for convenience of description. They are evidently composed of rocks of the Palæozoic series, which dip south-westward at an average angle of about 40 degrees, producing a steep escarpment-like front to the east. Elk Valley.

The river next flows south-westward for three miles, and then west for a like distance, in this part of its course cutting across the range just described. The valley is here narrow and bordered by high mountains, and is generally referred to as 'The Cañon,' though no really vertical rocky cliffs rise from the river, and at the lower end the mountains recede gradually, leaving rather wide flats, which are covered with fine timber, still unburnt, including much cedar. The rocks of the range cut through by the river are chiefly limestones, those seen near the trail resembling those of the lower part of the section on Crow Nest Lake; but higher up the slopes, much crinoidal limestone, like that of the upper part of the Crow Nest Lake section, must occur, as the *débris* in rock-slides is largely of this character. Specimens of fossils, including a small *Productus*, which resembles *P. Hallanus*, were collected here. This would indicate a Carboniferous age for the limestones. On the west side of the range, rocks of the Cambrian series, coming out beneath the limestones, owing to the easterly dip, form all the lower hills. "The Canyon."

On reaching the west side of the range, the river turns abruptly to the south, reaching the Elk River bridge a mile and a half lower down. After nine and a half miles of a south-westerly course, the Elk flows into the Kootanie River. The Crow Nest Pass may be said to terminate at the bridge, where the description of the North Kootanie Pass, given on a former page, also ends.

Cambrian rocks at the bridge.

The Cambrian rocks above alluded to are well exposed on some high hill-sides, followed by the trail near the west end of the narrowed portion of the valley; also in the banks and hills overlooking the river from a short distance above to several miles below the bridge. The most characteristic rocks are here greenish and greenish-grey quartzites, often of a very fine grain and regularly bedded. In these some layers are calcareous, weathering to a brown colour, the calcareous material being finely interlaminated with the siliceous, and in many cases forming remarkably twisted layers. These are evidently rocks of the same character as those described as "elephant's tooth limestones" in Mr. Bauerman's report, previously referred to.*

Elk River bridge beds.

Some of the calcareous layers hold numerous small, spherical, silicious concretions of an oolitic character. Quartzose argillites are also present, and some beds of red ripple-marked sandstones. The attitude of the Cambrian strata is here not far from horizontal, and the massive greenish quartzites are supposed to occupy a position far down in the great Cambrian series of the mountains. For convenience of reference they may be provisionally designated the Elk River bridge beds.

Canyon.

The bridge is thrown across between two rocky cliffs, at a height of about fifty feet above the stream, which here begins its plunge over a series of small falls and through wild rapids into the deep and narrow gorge—a true cañon on a small scale—which it occupies from the bridge to the mouth of the Wigwam. This cañon is due to the fact that the massive quartzites are regularly jointed at right angles to their bedding planes, enabling the stream to quarry them away block by block and leave wall-sided cliffs.

Vegetation and timber.

The change in character in the vegetation met with in crossing from the east to the west side of the Rocky Mountain Range has already several times been adverted to, and is of the same general character in all the passes, being that from a dry region to one of very considerable precipitation. It is nevertheless of interest to note the point at which some of the more characteristic forms appear in each instance. On the west slope of the eastern or watershed summit, the woods, already described as of fine growth, consist of *Picea Engelmanni*, *Pinus Murrayana*, *Pseudotsuga Douglasii*, and *Abies subalpina*. *Pachystima myrsin*

* See Report of Progress, 1882-84, p. 30 B.

ites was seen for the first time near Marten Brook. The cedar (*Thuya*) was first observed near the head of Coal Creek, and is abundant along the route followed thence, westward. *Sphæralcia rivularis*, *Spiræa betulifolia*, *Pteris aquilina*, var. *lanuginosa*, and in the same vicinity white birch (*Betula papyrifera*), were noticed in undergrowth on Coal Creek. Larch (*Larix occidentalis*) first appears about two miles from the mouth of the same stream. *Fatsia horrida*, not abundant in any part of the Rocky Mountain Range, properly so called, is established in a few places near the narrow portion of the Elk Valley. On emerging on the wide valley of the Kootanie, we pass at once from a humid mountain climate to a dry, lightly-timbered plain, which is often quite park-like, with an open growth of *Pinus ponderosa*, *Pseudotsuga Douglasii*, and *Larix occidentalis*, the last-mentioned appearing as tall, narrow, scanty foliaged trees, in many cases one hundred and fifty feet in height and three feet through at the base. *Purshia tridentata* is here common, and *Batsamorhiza sagittata*, last seen in the eastern foothills, reappears.

Head-waters of the North Fork of the Old Man River, and North Fork Pass.

Drainage area.

Like the Middle Fork of the Old Man, the North Fork breaks through the outer or Livingstone Range as a large stream, carrying the waters of an extensive tract of Cretaceous hills which forms the continuation of the Crow Nest Cretaceous trough, and intervenes between the Livingstone and High Rock ranges. Unlike the Middle Fork, however, the North Fork derives none of its waters from the western side of the High Rock Range, this range here constituting the actual watershed.

Surveys.

In 1881 our surveys were carried as far as the outer edge of the Palæozoic rocks of the Livingstone Range, but as it was late in the autumn, and heavy snow-storms, with every appearance of winter had set in, I was unable to penetrate this range for the purpose of ascertaining whether the Crow Nest trough, which had been discovered a few days previously, extended so far to the north. In 1883 a special trip was made for this purpose, but having been unable to learn anything of the character of the country within this part of the Livingstone Range, we were not prepared for so great an extent of Mesozoic rocks as actually exists, nor to find so many and such long tributaries; so, after examining the South-west, North and North-west Branches to their sources, and exhausting our whole stock of provisions, we were obliged to return. In 1884, the head of the West Branch was reached by the North Fork Pass, from the

Elk River, and a survey carried through from the North-west Branch to the southern sources of the Highwood River, thus completing the examination of all the main tributaries of the Old Man River.

North Fork Gap

The Livingstone Range,* where cut through by the North Fork, is quite narrow and abrupt, and though probably nowhere much surpassing 7,000 feet above the sea-level, is, owing to its rocky character, almost destitute of trees. 'The Gap' of the North Fork, as it is locally named, is a narrow rugged gorge crossing the range with a double curve somewhat in the shape of the letter S, and about a mile and a half in length. The river is very rapid in this part of its course, but shows no abrupt fall, and though the track at present existing through The Gap is rough, it would not be impossible, with a small expenditure, to make a practicable cart road to the open country beyond. The trail follows the south side of the stream, at first at a considerable elevation above it, but toward the west end, coming down to its level. Near the eastern end are

Indian cairns

three cairns; the first, a wide mound, about eight feet high, composed of stones and small boulders, and evidently very old, the two others smaller. As these are of no use as landmarks, they have probably been formed in the course of years by the addition of a stone by each Indian entering the mountains by this route, 'for luck.' On a narrow piece of flat open ground, a short distance further on, are the obscure remains of a couple of rectangles formed of larger stones. This place is well known to all the Indians, and named by them the "Old Man's playing ground." It is from this spot that the Old Man River derives its name, many superstitions attaching to the neighborhood. The 'Old Man,' Wī suk-i-tshak of the Crees, is a mythical character, with supernatural attributes, familiar under one name or other, to all students of American folk-lore.†

Livingstone Range

The Livingstone Range here appears to have the structure of a compressed anticlinal, slightly overturned eastward and with a sharp synclinal pucker near the top, in consequence of which a few beds of flaggy dolomite, of an arenaceous character like those often found near the summit of the limestone series, are folded in at the crest of the range. The same beds are found dipping westward at the west end of the gorge. The mountains seem to be entirely composed of limestone, which in most places resembles the cherty upper portion of the series, as seen on Crow Nest Lake.

* In a map compiled by J. Arrowsmith (1862). The part of the Livingstone Range of Blackiston, between the North Fork and Highwood River, is named Cowagh Mountains. See, British Columbia and Vancouver Island, by D. G. F. Macdonald, London, 1862.

† The name of the Old Man River in Cree is *Is-a-enoo-mut-cwe-win-si-pi;* in Stoney, *Is-as-ga-win-ih-ska-da-wap-ta.* It will be sufficiently obvious why these names have not passed into common use.

The Livingstone Range once passed, a country of lower rounded hills is entered, which resembles in all essential respects the rougher portions of the eastern foot-hills. The lower parts of the valleys which converge in it towards The Gap, are wide, and show long stretches of meadow and prairie, the total area of which, including that of open hill-sides, cannot be less than 19,000 acres. There is reason to believe that the snow-fall here is less than in the higher foot-hills, and a considerable number of cattle or horses would find abundant pasture.* Valleys west of range.

Just within The Gap, the valley of the North Fork bifurcates, the main hollow running north along the inner side of the Livingstone Range, the second, occupied by a stream which may, from the general trend of its valley, be called the South-west Branch. This, and the other branches of the North Fork will now be described in brief terms.

The valley of the South-west Branch runs for about four miles in the direction indicated by its name, and for this distance presents a succession of prairie flats, with frequent open, grassy hill-sides to the north. It is in some places nearly half a mile in width. Beyond this point, it is more contracted, and the hills on both sides are wooded, with numerous burnt patches and wind-fall, which obliged us to follow the bed of the stream itself. In this way we travelled a further distance of four miles, attaining a point within less than four miles of the base of the High Rock Range. The stream here became impracticable for our animals, owing to its rocky character, and it had dwindled to a very small size. Having ascended a high hill from which the country to the west was completely overlooked, it was determined not to expend further time and labour in forcing a passage in this direction. This part of the axial range was observed to be an unbroken and wall-like mass of limestone, with an average altitude of about 7,000 feet. To its base, and running out from it at various angles, attach long, steep-sided spurs of Cretaceous rocks, bare of trees, and more or less uniformly covered with grass and low alpine vegetation, their higher portions attaining elevations rather greater than 6,000 feet. They are separated by deep V-shaped valleys filled with dense green woods. Though not extremely rugged, the mountain scenery here, from its varied outline, and the contrasts in colour between the pale limestone peaks, the light-green meadows of the higher slopes and the sombre forests of the hollows, is peculiarly pleasing. South-west Branch. High Rock Range.

Though cutting almost directly across the Cretaceous trough, the geological section afforded by the South-west Branch is not particularly instructive. Immediately west of the edge of the limestone, sandstones Section on South-west Branch.

* For some unknown reason the mountains in this particular region are known to the Indians as the 'Home of the Cold,' *Kis-in-wi-ki* in Cree, or *Ti-sai* in Stoney.

and conglomerates are found dipping westward, but at lower angles than the limestone. For some miles the beds are rather irregular, both strike and angle of dip varying much, so that it would require very detailed work to make out a clear section; they appear, however, to form a synclinal, followed by an anticlinal fold, which is succeeded by a great thickness of beds dipping generally westward at high angles. At a point six miles up the stream, one hundred feet or more of blackish sandy shales occur, the beds being nearly horizontal, and probably resting in a wide synclinal. These may represent the shales which lie several hundred feet above the coal-bearing horizon on the North-west Branch. Beyond this, as far as examined, the rocks have general westward dips at angles of about 30 to 40 degrees. Fragments of Cretaceous volcanic rocks, like those described on the Crow Nest Pass, are found in some abundance in this stream, and it is probable that the beds from which these fragments come, cross the stream at a point higher up than was examined. No fragments of coal were observed in the gravel or wash of this stream.

West Branch. The West Branch joins the North Branch at a point two and quarter miles above The Gap. The valley leaves that of the North Branch at a right angle, and runs nearly due west for ten miles to the base of the watershed range. For three miles it is somewhat narrow and cuts through a series of high sandstone ridges, which strike nearly north-and-south. In this part of its length it is about half-wooded, with many little meadows and grassy slopes to the north. The hills then fall away and become lower, and an extensive prairie, with an area (without counting the grassy slopes of higher hills) of about a square mile, appears on the north side. This is known to the Stoney Indians by an unpronounceable name, meaning the "Prairie where the Kootanie child died." Thence for about six miles the valley is again rather narrow, but the bordering hills are low, and as viewed from a height, the country is almost plateau-like, and nearly everywhere wooded. This uniformity leads to the belief that the Cretaceous rocks are here little disturbed, which is further borne out by the attitude of the rocks themselves wherever seen. Along the valley is a considerable quantity of timber of fair growth, and very little of it has so far been destroyed by fire. The trees are spruce (*Picea Engelmanni*), black pine (*Pinus Murrayana*) and balsam-spruce (*Abies subalpina*). There are also, along this part of the valley, numerous open glades with good pasturage for animals. The last of these is situated due south of the summit of a high, rough, limestone mountain, which is in sight from many points during the ascent of the valley, and constitutes a remarkable outlier of the main range. This mountain is supposed to be identical with that seen from a distance by Capt. Blackiston, and named by him Gould's Dome.

Prairie.

Timber.

Gould's Dome.

On reaching the eastern slope of the main range, the valley turns to the north, and runs between this and the southern spur of Gould's Dome, for two and a half miles. The stream is here quite small, being about ten feet wide by three inches deep, and the valley running on to the north, evidently leads over in a few miles to the North-west Branch. On reaching the point above indicated, the main range is ascended by a series of sharp zig-zags through thick woods, and the summit is crossed by a rough valley, nearly half a mile in width, flanked to the north and south by bare, though rather rounded limestone mountains. This pass, which, as far as I know, had not been traversed, except by Indians, till crossed by us in 1884, may be named the North Fork Pass. The height of the summit is 6,773 feet, the rapid ascent from the brook to the east being about 550 feet. The valley at the summit is for the most part open and grassy, a fact due to the destructive effect of the winter avalanches from the adjacent mountains, rather than to the elevation, which, in itself, is not sufficient to prevent the growth of forest.

Summit on North Fork Pass.

The section of the Crow Nest Cretaceous trough seen on the West Branch, which cuts across its entire width, has a pretty exact parallelism with that on the South-west Branch. It is shown, more or less diagramatically, in section No. 3. The sandstones and conglomerates dip off the west slope of the Livingstone Range, forming first a low synclinal, followed by a couple of low anticlinals. After about two miles, characterized by pretty regular westward dips, another wide synclinal is crossed, beyond which westerly dips were again observed. Opposite the southern end of Gould's Dome, the beds are nearly flat, and a tongue of Cretaceous rocks evidently runs north between this mountain and the main range, though whether this inosculates with the same rocks on the North-west Branch or not is uncertain. Gould's Dome appears to be entirely composed of limestone, with a synclinal structure, while the limestone rocks of the main range dip persistently westward at angles of 40 to 50°. Neither the contemporaneous volcanic rocks of the Cretaceous nor any coal seams were found on the West Branch.

Section on West Branch.

In descending westwards from the summit, the north side is followed of the valley of a stream, most of the way through thick woods, but at one place along the edge of a high cliff of limestone. Here an extensive view is obtained to the south, where rounded and densely wooded ridges are seen succeeding the bare central portion of the main range to the west. Four miles from the summit, the trail reaches the junction of the stream followed, with a second, coming from the north, and about equal in size. The united streams flow then south-westward between gravelly flats, more or less densely wooded, till they

Country between summit and Elk River.

reach the eastern base of a narrow, abrupt limestone range, which still intervenes between this point and the valley of the Elk River. This range, which it is proposed to call the Wī-suk-ī-tshak Range, runs parallel with the High Rock Range, nearly north-and-south. It ends to the northward in about six miles, and to the south may continue for a greater distance. It is cut completely through nearly at right angles, by the stream followed by the trail. The passage thus made is a narrow, rocky defile, bordered by cliffs and crags, and about two miles in length. The trail is rough, and crosses the stream a number of times. A fall of about fifteen feet occurs at one place. After thus passing the Wī-suk-ī-tshak Range, the great valley of the Elk River, here about three miles in width, is entered, and the North Fork Pass may be said to end.

Wī-suk-i-tshak Range.

Rocks between summit and Elk River.

The limestone strata of the western slope of the High Rock Range, dip westward at moderate angles, and are overlain by hard Cretaceous sandstones, which occupy the valley between this and the Wī-suk-ī-tshak Range, with a width of about two miles. So few exposures of these rocks were seen, that their attitude cannot be stated with certainty, but they probably form a synclinal tongue, connected to the north with the main mass of Cretaceous rocks which here occupies the Elk Valley. Rolled fragments of bituminous coal were found in the northern branch of the brook previously described. The Wī-suk-ī-tshak Range shows, where traversed, two anticlinal folds, with an intervening synclinal, and consists of rocks of the limestone series, which here, however, includes a wide zone of brown-weathering quartzite. This, in some places, holds frequent small pyritous concretions, while the limestones are often cherty. The eastern anticlinal in this section is rather low, while the western is slightly overturned on the intervening synclinal.

Character of North Fork Pass trail.

While the traverse above described by the West Branch of the Old Man and across the summit to the Elk has been spoken of as following a 'trail,' it should be explained that it appears to have been very little used as a connected route. We found a moderately well-beaten track in some places, while in others scarcely any vestige of trail exists. This pass might be made part of a through route to the Columbia-Kootanie Valley by utilizing a trail, reported by the Indians, which leaves the west side of the Elk Valley nearly opposite the point at which it enters the same valley from the east. This trail is stated to cross by the head-waters of Bull River to the Kootanie and to reach the latter a few miles above the point at which it leaves the mountains. The impossibility of fording the Elk River, however, at times of high water, would render this route precarious.

The North-west Branch of the North Fork joins the North Branch or Livingstone River at a point five and a half miles north of The Gap. The valley first runs two and a half miles nearly due west, then eight and a-half miles in a general bearing of N. 45° W. to the fall, and finally a similar distance—turning first a little more to the north and then rather to the east of the last bearing—to its termination at the base of the High Rock Range. North-west Branch.

We camped at the upper end of the east-and-west or lower part of the valley on the evening of August 8th, 1883. Up to this point the valley is wide, with open terraces and grassy hill-sides to the north, the stream, where not confined between low, rocky cliffs, being about fifty feet wide by one foot deep, and everywhere rapid. The hills bordering the valley, which are low near the mouth of the stream, become high and bold near the point designated, the valley here cutting through a well marked range, which runs for many miles northward. For about a mile above this point, the valley maintains the same character, but further on becomes more contracted, and generally wooded, with much tangled wind-fall in places and only occasional grassy meadows. On the lower part of this portion of the valley the bordering hills are broken, but further on assume the character of wide ridges, rather plateau-like in aspect, and attaining an elevation of about 1,200 feet above the valley in some places. Two streams, apparently of some size, come in from the southward, and two from the north, one about six, the second about fifteen feet wide. The trail—a Stoney Indian hunting-track—follows the left or north-east bank. Character of the valley.

The fall is about thirty-five feet in total height, and notwithstanding the quantity of standing and fallen burnt woods with which the hills are here covered, its surroundings are very picturesque. A valley, carrying a stream of some size, opens from the south-west just above the fall, and affords a grand view of the limestone mountains of the watershed range, here about two and a half miles distant. Though the peaks in the vicinity scarcely exceed 8,000 feet above the sea-level, their forms are singularly bold and varied, one of the nearest culminating in vertical, organ-like columns. A round-topped mountain, much resembling the Crow's Nest in outline, standing a little in advance of the main range and higher than it, has an elevation of about 8,500 feet. This is about four and a half miles west-north-west of the fall, and, on account of its peculiar form, may be called Bee-hive Mountain. For the benefit of future travellers, I may add that there is an excellent camping ground, with good pasturage, just above the fall, while the deep pool below is a good fishing place. Valley near the fall. High Rock Range.

Upper part of valley.

The weather being extremely wet, and the valley above apparently very much encumbered by wind-fall, Mr. Tyrrell, my assistant in 1883, proceeded on foot in search of a practicable route to the head-waters of the main stream, while I ascended a high hill to the south of the fall, for the purpose of sketching the topography and gaining such knowledge of the region as the clouded condition of the atmosphere would permit. Having ascertained that the upper part of the valley was not so difficult as had been supposed, we travelled the next day almost to the base of the High Rock Range, and there choosing another observation point on a high spur of the range, obtained sketches and bearings of the whole surrounding country.

A high sandstone and conglomerate ridge, which abuts on the valley at the fall, runs boldly northward, and was again recognized on the head-waters of the Highwood, sixteen miles distant. Beyond this ridge, the valley is continued in a north-westward direction for about five miles, cutting very obliquely across a series of parallel strike-ridges. This part of the valley contains several grassy glades, but is frequently obstructed by burnt and fallen timber. The valley then turns westward, cutting almost directly across the strike, and becoming at the same time, for about two miles, quite open, with low bordering ridges, or plateau-like elevations. The stream, reduced to a mere brook, winds through swampy meadows with thickets of *Betula glandulosa* and other northern forms. The immediate foot-hills and slopes of the limestone range are encumbered here with dense and nearly impenetrable wind-fall. Beyond, rise the almost absolutely bare and precipitous fronts of the main range, down which little cascades, forming the furthest sources of the Old Man, are observed to fall. From the north, no less than five streams join that of the main valley above the fall, with but one of any size from the southward. For about a mile, near the point at which the valley first turns westward, the stream itself flows between low rocky cliffs in the bottom of the valley. By the valley of the second stream from the north above this miniature cañon, we subsequently found a route to the southern feeders of the Highwood. The stream itself was named Oyster Creek, on account of the occurrence on it of banks strewn with fossil shells of this kind.

Geology of North-west Branch.

While the geological features, observed in crossing the Crow Nest Cretaceous trough by the North-west Branch, are largely a repetition of those already described on the more southern branches, and the obliquity of the general course of the valley to the strike, renders the section more obscure than on these, some points deserve special note. The sandstones and conglomerates, met with near the junction of this stream with the North Branch, dip uniformly westward from the flank

of the Livingstone Range. Between the Livingstone River and our camp of August 8th, above alluded to, two and a half miles west, the beds form a low synclinal, followed by a similarly low anticlinal, and at the point just designated, are found dipping S. 30° W. < 50°, and including seams of coal. The section shown in the bank at this place is as follows in descending order.— Coal seams.

	FEET.	INCHES.
1. Superficial gravels	—	—
2. *Coal*	1	0
3. Shale	0	1
4. *Coal*	2	6
5. Shale	0	4
6. *Coal*	5	6
7. Shale	0	6
8. *Coal*	0	9
9. Sandstone	2	0
10. Shale and coal	2	0
11. Sandstone and shale	2	0
12. Black shale	1	6
13. Sandstone	2	0
14. Black shale with coaly layers and some ironstone	9	0
15. Clay-shales and ironstone (to water)	6	0
	35	8

The total thickness of coal in the section is thus nine feet nine inches, but the top of the upper part of the seam is wanting. The coal is generally crumbling and soft, a circumstance, doubtless, largely due to weathering, though the numerous small cracks and slickensided surfaces observed show that it is naturally tender. Like some other coals in the mountain region it has probably been crushed by movement of the beds subsequent to its complete consolidation. Mr. Hoffmann's analysis of this coal shows it to be of excellent quality. It yields a firm coke, and contains water 1·24, volatile combustible matter 24·62, fixed carbon 66·61, ash 7·53. (See p. 9 M.) Coal.

A few fossil plants were collected which proved sufficient to show by the identity of species, that the coals here met with must be regarded as being in the same stratigraphical position as those described in the Crow Nest and South Kootanie passes. All these localities indeed, probably represent a single, persistently coal-bearing horizon. From this point to the fall no satisfactory general section was obtained. Fossil plants.

Less than half a mile below the fall, coal is again seen in the bank of the stream, associated with sandstones, ironstones and black shales. These rocks likely constitute another repetition of the horizon just referred Second coal outcrop.

to. The coal is here, however, almost completely pulverized and the section much compressed. The greatest observed thickness was about three feet. Strike S. 20° E. with a westward dip at an angle of about 60°. The fall is produced by massive sandstone beds associated with conglomerate, which cross the stream and probably hold a higher place in the series than the coal. Three miles above the fall, at the mouth of a considerable stream from the north, a bed of grey ash rock appears. The strike is about N. 17° W., and about twenty feet in thickness is shown. The exposure is a small one, but it appears probable that nearly the entire thickness of the bed is exhibited. The material, which, though properly speaking, an ash rock, might almost be called in places a fine-grained agglomerate, is evidently the representation here of the thick volcanic zone previously described on Crow Nest Pass. It resembles the similar rocks already noticed in being somewhat calcareous, and in the absence of quartz grains. This is the furthest point to the north at which rocks of this character were recognized in the Cretaceous, and they are here evidently dying out, the point of eruption having probably been not far from the Crow Nest Pass.

Volcanic rocks.

Plant-bearing beds.

The beds underlying the volcanic material, at less than a quarter of a mile up the same small stream, dip pretty regularly S. 58° W. at angles of 40° to 45°. They are greenish-grey, flaggy and shaly sandstones, with some blackish and reddish sandy shales and occasional conglomerate layers. Some of these beds yielded a number of fossil plants, which though imperfectly preserved, are stated by Sir J. W. Dawson to have important points of resemblance with those of the Dakota group, and to represent the same horizon as that from which plants were obtained near the mill on Mill Creek, in the foot-hills.* The following species were recognized.—†

Alnites insignis, (?) Dn.
Platanus affinis, Lesq.
Macclintockia Cretacea, Heer.
Laurophyllum debile, Dn.
Aralia, sp.
Paliurus montanus, Dn.
Juglandites Cretacea, Dn.

Thickness of strata.

The zone at which the plants occur was estimated to be about four hundred feet below the volcanic rock. By plotting the attitudes of the rocks intervening between the latter and the coal outcrop below the fall, the coal was estimated to be, approximately,

* See Report of Progress, 1882-84.
† Trans. Royal Soc. of Canada, Vol. III., Sect. IV.

2,200 feet below the same horizon, a thickness considerably less than that of the volume of strata between the horizons believed to be the same in the Crow Nest Pass. In the same brook coal fragments are found, and it is probable that the continuation of the coal seam is cut through not many miles further up.

Dark shales.

For about two miles above this occurrence of volcanic rock, the valley nearly follows the course of a series of black or dark-grey shales, with sandy beds not infrequently intercalated and some layers of ironstone. These have a thickness of at least 1,400 feet, and overlie the ash bed. A few fossils obtained from them appear to show that these shales represent the Benton group. Mr. J. F. Whiteaves has recognized among these *Inoceramus undabundus, Pholadomya papyracea, Scaphites Warreni and S. vermiformis?**

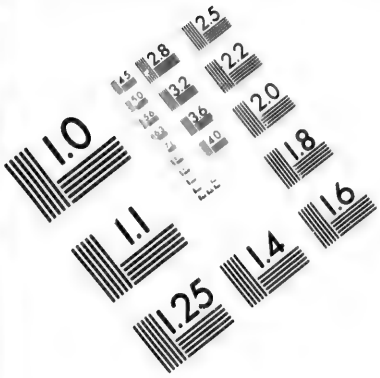
Highest beds of section.

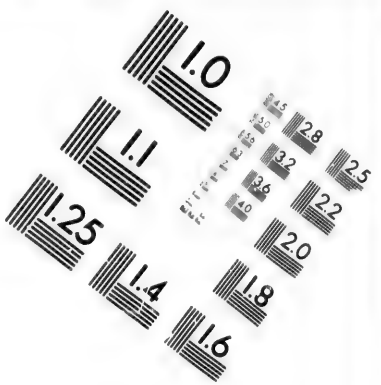
If the section still continues a regular one, in ascending order, the beds of the cañon-like part of the stream, above described, should represent the Belly River series of the plains. They are flaggy, hard and soft sandstones, with shaly layers, but all of rather pale colour. The dip is here S. 63° W. $< 25°$. If the Pierre shales follow these, they are passed over in the part of the valley without exposures. The sandstones nearest the base of the mountains are probably Laramie, as they are on the strike of those observed a few miles up Oyster Creek, which are known by their fossils to be of that age. They dip at low angles toward the mountains.

Livingstone River.

The valley of the North Branch or Livingtone River, is remarkably straight and runs nearly due north from The Gap. In its lower part it is in some places a mile wide in the bottom, and averages fully half a mile in width for a long way up. Its general aspect is very attractive. About half the area of the valley may be designated as bunch-grass prairie and meadow, and the soil is good, though evidently unfitted for cultivation, owing to the frequency of summer frosts, due to the altitude and proximity of the mountains. The vegetation resembles that of the foot-hills to the east. At a point about eighteen miles above The Gap, however, the characters change. The stream, which in its lower part generally occupies a rather deep channel in the valley-bottom, is here reduced to a small rapid brook, and its bed is little depressed. The flats are rough and stony, and the vegetation becomes sub-alpine. Swamps are frequent and hold a thick growth of willows and *Betula glandulosa*, while the woods consist of *Pinus Murrayana* and aspen, with a few Douglas firs, cottonwoods and Engelmann's spruce. The valley was followed up to a point nearly twenty-three miles from The Gap, where it bifurcates, the main stream—a brook

* See Contributions to Canadian Palæontology, Vol. I., Part I.





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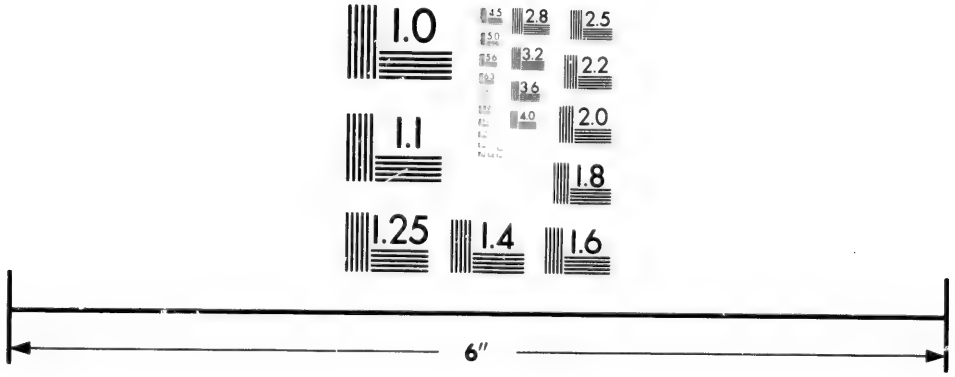

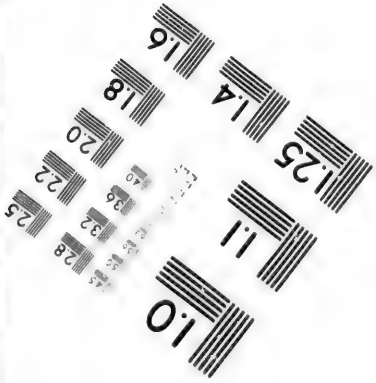

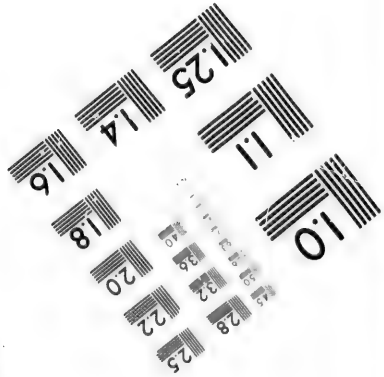

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twenty feet wide by six inches deep—coming from the north-westward through a narrow valley, while a trail going northward by a second valley crosses by an elevated pass to the head-waters of the Middle Branch of the Highwood in the foot-hills (see p. 94 B).

Livingstone Range.

The Livingstone Range, composed of limestone, constitutes the eastern side of the valley of the Livingstone River, while the Cretaceous rocks form the hills on the west. The stream flows, however, till near its head, altogether on the Cretaceous, the junction between the two series lying close in to the abrupt base of the limestone mountains. These are in general very steep, with much bare rock, scarps, cliffs and screes. The higher points rise about 2,000 feet above the valley, while the sandstone hills seldom attain 1,500 feet and are generally not more than 1,000 feet. The slope of the valley itself is considerable, yet the higher points of the hills and to a less degree of the Livingstone Range also, seem throughout to preserve about the same elevation relatively to it. The limestone range is most rugged in its southern half, and though generally showing westward dips, in places exhibits eastward ones. Northward, the summits of these mountains are generally rounded and bald, and evidently composed of rock crumbled in place.

Break in the range.

Though thus far spoken of as continuous, the Livingstone Range is interrupted for a distance of probably three miles, at a point about ten miles north of The Gap. The stream here turns away from the base of the range and for some miles is bordered on both sides by Cretaceous hills, which are continuous to the east with those of the outer foot-hills. Where the limestone range resumes, it appears to represent a distinct anticlinal fold, the axis of which lies further to the east. One tributary from the east flows completely through the Livingstone Range, while two others enter through the break above referred to. The larger tributaries, however, come from the westward, of which the West and North-west Branches, previously described, are the most important. Another rapid stream —seventeen feet wide by six inches deep,—enters from the west, twenty miles from The Gap, and near this point the edge of the limestones turns westward, the strike changing to the same direction. The Cretaceous hills to the south of the stream are steep and escarpment-like, and constitute the end of a well-marked high range, which runs southward about ten miles, parallel to the main valley and a few miles west of it. The sandstone hills, of which this constitutes a part, form a broken, irregular country, with narrow valleys and are almost uniformly wooded. The forest has not been much destroyed by fire, but the timber is only of fair quality and not very large in size.

Twenty-mile Creek.

The limestone of the Livingstone Range, as far as examined, appears chiefly to resemble that of the upper cherty beds of the Crow Nest Lake,

though there is also some crinoidal limestone. The banks of the Livingstone River show fine sections of Cretaceous rocks, though, as the stream nearly follows the strike, the same zones constantly recur. Grey or brown sandstones, sometimes rather massive, alternate with coffee-coloured, or bottle-green, crumbling and shaly sandstones, and occasional beds of ironstone. For about three miles above the entrance of the North-west Branch valley, the Cretaceous rocks are much disturbed, and are in places nearly on edge. Rocks of Livingstone Range.

In the wash of a stream entering at fifteen miles from The Gap, and again in that of the Twenty-mile Stream, above alluded to, fragments of coal occur, and it is probable that closer investigation will bring to light a number of coal outcrops in the vicinity. The lower part of the Livingstone Valley shows in many places thick beds of rounded gravel overlying the Cretaceous; and narrow terraces occur several hundred feet above the stream in some localities. In the upper part of the valley a deposit resembling boulder-clay, and charged with large sub-angular limestone blocks appears, forming terraces eighty feet above the stream. No glaciated stones were, however, found, nor were any striated rock-surfaces observed. The gravel of the streams is remarkably local in origin in all this part of the mountains, and there is little apparent evidence of extensive glaciation. Coal. Gravel deposits.

The following are the elevations of some points on the branches of the North Fork of the Old Man River, within The Gap, barometrically determined, and in each case referring to the water-level of the stream :— Elevations.

North-west Branch.—Eight miles from Gap (2½ miles above mouth of this branch) 4,966 feet. Above the fall, 5,512 feet. Near source, about half a mile from base of main range, 6,311 feet.

Livingstone River or North Branch.—Two miles from Gap, 4,709 feet. Sixteen miles from Gap, 5,371 feet.

Head-waters of the Highwood River.

The southern sources of the Highwood River were reached by following up the tributary of the North-west Branch of Old Man River, which has already been alluded to under the name of Oyster Creek. The trail followed, which is rather an Indian hunting-track than a regularly travelled route, crosses and re-crosses Oyster Creek and small streams joining it, till about four and a half miles from the valley of the North-west Branch, the watershed between this and the Highwood is crossed, and Lost Creek, a tributary of the Cataract Branch of the Highwood, is reached. Oyster Creek and Lost Creek flow in opposite Trail to Cataract Branch.

directions in a persistent valley, with a nearly north-and-south bearing, which lies along the base of the westernmost of the series of parallel Cretaceous ridges which characterize the country between the Livingstone and High Rock limestone ranges. This valley is at an average distance of about three miles from the crest of the latter range, and is separated from its base by irregular wooded hills. The High Rock Range, though here sinuous with regard to the line of its crest, is continuous and wall-like toward the east, and crowned at intervals by bare, rugged summits of irregular and striking forms. The limestone rocks composing it have a persistent westward dip and several high, bare, flat-topped ridges project eastward from its base.

Oyster Creek.

In following up Oyster Creek, the country is generally wooded, though the trees are, as a rule, small, and there are numerous little meadows in the valleys. The elevation of the summit is 6,226 feet, and the country gradually descending northward from this point is densely wooded, though the trees are here also usually not of great size. The first little prairie occurs at about three miles from the summit. At six miles from the summit, this tributary of the Cataract Branch, abandoning its northward course, turns abruptly eastward.

Laramie rocks.

The valley follows the general strike of the rocks throughout. Near the head-waters of Oyster Creek, sandstones and shales, generally of a soft character, are well exposed in the banks, and dip nearly due west at angles of 45° to 50°. A massive bed also occurs, which is composed almost entirely of oyster shells, and exactly resembles some of those seen in the eastern foot-hills near the 49th parallel. (See Report of Progress, 1882-84, p. 55 C.) They are overlain by soft shales and sandstones, holding coal-seams, of which the thickest observed is about two feet. Just north of the watershed, the same coal-bearing horizon is again seen in several places, and though the seams are here all quite thin, it is not impossible that thicker ones might be found in this vicinity.

Coal.

The coal found at this place is a true bituminous one, yielding a firm coke, but a specimen examined contained 24·69 per cent. of ash. (See Report by Mr. Hoffman, p. 8 M.)

Fossils.

The *Ostrea*, above referred to, has been determined by Mr. Whiteaves to be *O. glabra*, var. *Wyomingensis*. *Corbicula occidentalis* occurs in the same bed in smaller numbers, and silicified wood is also found. The horizon is almost certainly near the base of the Laramie, and the locality is interesting as being almost the only one in which beds of this age have been clearly recognized in the mountains. The greater part of the space between the valley of Oyster and Lost creeks and the base of the mountains, may be underlain by these rocks.

Another point of interest is the entire absence of gravel deposits about the summit between Oyster Creek and Lost Creek, where even the smallest rills cut channels into the beds above described. Lower down on both streams, gravelly and other detrital deposits are met with in the usual abundance, and include much limestone from the adjacent mountains. Absence of gravel deposits.

The part of the valley of the Cataract Branch, into which Lost Creek falls, runs nearly east-and-west from the base of the High Rock or watershed range to the outer Highwood Range, which forms a northern continuation of the Livingstone Range. Its western extremity rises rapidly toward the base of the High Rock Range, and is wide and shallow, bounded by low-wooded hills, with open alpine meadows toward the higher levels. Eastward, it becomes a deep trough, and cuts directly across five or six high Cretaceous ridges. Of these the most important is the central one, which attains a height both to the south and north of the valley, of about 2,000 feet above it. The point to the north, which was ascended, affords a very fine view of the upper east-and-west part of the valley of the Cataract Branch, which has a length of about eight miles, and the contrast is very marked between the high parallel ridges, characterizing the eastern part of the Cretaceous area, with the gentle flowing outlines of the hills forming a belt of several miles along the base of the High Rock Range. This difference is no doubt dependent on the different attitude of the rocks, which in one case form a series of sharp folds, in the other, whether in this normal position or—as may very likely be the case—completely inverted, lie at comparatively low angles. Country near Cataract Branch.

The east-and-west portion of the Cataract Branch valley contains many patches of prairie along the stream, and these often run up on the southward-facing slopes to a considerable elevation. The woods are not much destroyed by fire, but the size of the trees is small. At the foot of the Highwood Range is a rather large, triangular, flat, terraced area, in which a small stream—Salter's Brook—coming from the pass which leads across the range to the eastern foot-hills, joins the river. It was our intention to follow the river now called the Cataract Branch to its junction with the main Highwood, but about two miles below the mouth of Salter's Brook, the valley, running northward along the base of the Highwood Range, becomes narrow and densely wooded, and we came abruptly to the edge of a gorge, into which the river plunges, making a picturesque fall, the upper leap of which is about ten, the lower about thirty feet. Finding no vestige of a trail beyond this point, and the character of the valley rendering it evident that it would be difficult if not impossible to take our animals further, we turned back to Salter's Brook and crossed the Highwood Range. Cataract Branch valley. Fall.

Cretaceous rocks.

No features of special geological interest were observed during the traverse of this part of the Crow Nest Cretaceous trough. The strike of the rocks varies from N. 34° W. to N. 22° W., and the dips are almost uniformly to the south-west at very high angles, the beds becoming vertical in some places. Two considerable belts, characterized by dark shales and shaly sandstones, cross the east-and-west part of the Cataract Branch valley. One about a mile wide, just east of the mouth of Lost Creek, the other, probably less important, about a mile above the mouth of Salter's Creek. The remaining rocks are sandstones with some conglomerate, which are often considerably indurated and weather to a brownish colour. Each of the shale belts probably consists of several compressed folds, giving an appearance of very great thickness. The first or western belt is apparently continuous with that described on the North-west Branch of the North Fork (p. 89B).

Limestone series.

Just above the fall, the limestones of the Highwood Range first appear on the river with a dip of N. 82° W., at an angle of 5°. These limestones weather brownish, and have the appearance of the beds of this series frequently found immediately underlying the Cretaceous. At the fall, the limestones are of the usual blue-grey colour, and dip S. 73° W. $<$ 20°. The limestones of the western part of the Highwood Range dip westward at angles of 35 to 40 degrees, and as this is nearly the slope of the mountain sides, wide, flat surfaces of bare rock are exposed.

Pass over Highwood Range.

In following Salter's Brook eastward, toward the summit of the pass over the Highwood Range, it is soon found to become a rough stony torrent-bed, which we were obliged to cross and re-cross. The valley is now contracted and the mountains rise abruptly on either side to a height ofa bout 2,000 feet. The summit is reached at about four miles after leaving the Cataract Branch, and has an elevation of 6,398 feet. The descent to the east is at first very steep, and leads down into an amphitheatre, open to the north, and bounded to the east by Sentinel Mountain, which forms a high projecting spur of the limestone range. The scenery is of a wild alpine character, and several streams from the encircling mountains fall toward the centre of the great depression, forming the sources of the Middle Branch of the Highwood River. There is probably here a synclinal fold of Cretaceous rocks, compressed and overturned between the limestone masses forming the range just traversed on one side and Sentinel Mountain on the other. The Cretaceous rocks are, however, much disturbed and irregular, and the synclinal runs out to the southward against a high irregular mass of limestone mountains, across which, we were informed, an Indian trail runs to the head of the Livingstone River. It is a somewhat remarkable fact that the sources of Salter's Brook are actually on the Cretaceous sandstones

to the east, and that it runs completely across the limestone belt of the Highwood Range. This circumstance shows, that when hardened, the Cretaceous sandstones are capable of affording to denudation a resistance as great as the older limestone series.

Middle Branch of Highwood River.

From its source, the Middle Branch of the Highwood runs in a direction a few degrees east of north for seven miles, beyond which point it turns eastward. The valley is at first deep and shut in by high, steep foot-hills, but as it gradually recedes from the base of the Highwood Range, it becomes more open. Successive fires have almost entirely removed the wood from the upper part of the stream, and the slopes have become grassed, with the irregular, scanty growth often observed in the high and bleak parts of the foot-hills. Before reaching the point at which this stream bends eastward, however, several luxuriant prairie patches interspersed with coppice are passed through. No detailed examination of the Cretaceous rocks of this part of the foot-hills was made, but an important band of dark shales appears nearly to follow the upper part of the stream and running across the intervening country to the main stream of the Highwood, gives rise to a wide, low valley.

Comb-like foot-hills.

The foot-hills, bordering the Highwood Range in this vicinity, run out in a series of long, comb-like spurs, nearly at right angles to the range, and to the general direction of strike. This peculiarity, which is again referred to, is in marked contrast to the usual system of strike-ridges met with in the foot-hills and other folded Cretaceous areas. It would appear that where the Cretaceous rocks form the flanks of a dominant range, the streams, for some reason, tend to follow lines of transverse fissure rather than the strike.

Highwood Valley.

Following up the so-called North Branch of the Highwood, which is in reality the main stream, we again entered the mountains, eight miles north of the pass just described. The Highwood Valley, in the foot-hills adjacent to the mountains, is a wide depression, with prairie flats and terraced sides. The hills near it are from one-half to two-thirds wooded, chiefly with aspen, but much of the wood is dead and blackened by fires.

Highwood Gap.

The gap, or gorge, by which the river leaves the Highwood Range, is narrow, the elevation of the river at this point being about 4,780 feet. The Cretaceous rocks east of the range dip toward it, or westward, at angles of 30° to 35°, but on approaching their junction with the limestone, become vertical and show evidences of very great pressure. The line of junction appears to follow the crest of a high ridge for some distance south of the river. The limestone series forming the Highwood Range has, on the river, a transverse width of about two miles, and probably presents the usual anticlinal structure as the dips are westward, and the limestones are again followed to the west by the Cretaceous series. The

mountain mass to the north of The Gap, of which only the high spurs
Mount Head. are seen in following the river, I take to be Mount Head, of the maps. A mountain with this name appears on Palliser's map, and has been given great prominence on several more recent maps, but I have been unable to ascertain by whom the name was applied, or to find any description or bearings by which it might be satisfactorily identified. It may probably have been a peak seen from the eastern plains or foot-hills at a great distance. Its latitude, and position in the eastern range of the mountains, as shown on Palliser's map, accord nearly with the mountain here referred to, and under the circumstances there is no reason why the name should not be preserved in connection with this mountain, even if it be not that originally intended.

Change in trend of range. The Highwood River breaks through the outer range at a point at which the latter suffers a marked change in trend, running more to the north-westward, and making an angle of nearly fifteen degrees with its former general course. The High Rock Range to the west, and the intervening Cretaceous ridges of the northern part of the Crow Nest Cretaceous trough, participate in this changed trend, which must therefore be of some structural importance.

Highwood Valley in the Mountains. Within the Highwood Range, the river-valley runs westward for about two miles, crossing a series of Cretaceous ridges, like those seen on the corresponding portion of the Cataract Branch. The rocks, so far as exposed, are usually sandstones, varying in texture, and in colour from yellowish and brownish to greenish-grey. The dips are westward at an average angle of about 60°.

From the point last mentioned the valley turns to the north-westward, occupying nearly the centre of the Cretaceous area between the two limestone ranges, for a distance of twelve miles, when, by the interpolation of a third range of limestone mountains, of which Mist Mountain constitutes the southern extremity, the Cretaceous trough is divided into two branches, the stream at the same time bifurcating. The western branch—Storm Creek—occupies a valley which runs across to the Kananaskis, the eastern—Mist Creek—rises six miles north from the forks at the base of a high transverse ridge formed by the inosculation of the foot-hills of the Mist and Highwood ranges.

Character of the valley. From The Gap to the forks, near Mist Mountain—a distance of fourteen miles—the valley contains a number of prairie patches, but becomes more generally wooded on toward the forks. The river at the forks has an elevation of 5,736 feet. The hills on both sides are, as a rule, rather densely wooded, and several small tributary streams fall in, both from the Highwood and High Rock ranges. About six miles up the river from The Gap, an indistinct trail, which we had followed so far, was lost, and in trying back, we fell upon an old trail,

which for about three miles, runs parallel to the river, behind a low intervening ridge. This trail, though now obstructed by wind-fall, has evidently at one time been much travelled, and, I believe, formed part of the north and south 'pitching trail' of the mountain Indians.

The Cretaceous hills to the east of this part of the river are high and rough and are broken at intervals by torrent-valleys which bring down the waters of the Highwood Range. This range was here not well seen, but so far as observed, the limestones appear to dip southward at high angles. In the High Rock Range, on the contrary, the limestones lie at comparatively low angles, though dipping in the same direction. The hills intervening between the river and the High Rock Range, are again comparatively low and gently rounded, and are densely wooded. The range itself resembles in character that near the head-waters of the North-west Branch of the Old Man, and has some summits with remarkable block-like forms. One very high, pointed mountain is nearly on the latitude of the Highwood Gap.

Pass between Highwood and Kananaskis.

In following up Storm Creek ten and a half miles, between the Misty Range and a parallel range on the west, a summit separating the waters of the Highwood and Kananaskis, is reached. The valley is continuous and straight, and the Kananaskis Valley, at a distance of about four miles, may be seen from it. This summit, which has a height of 7,217 feet, is very nearly in the same latitude with that between the Kananaskis and the Elk (p. 107 B), and only three and a half miles distant from it, with one intervening range. Bearings were obtained from this point on mountains previously fixed on the Kananaskis, but my examination was not carried beyond the summit.

Storm Creek.

Storm Creek, is really the main source of the Highwood, and carries nearly twice as much water as Mist Creek. The valley is generally wooded, and is rather narrow and rough for a few miles above its mouth, after which it becomes wide and flat bottomed, and runs parallel to the enclosing ranges. The woods have not yet been much destroyed by fire, and some trees of very fair growth occur in the upper part of the valley. The elevation becomes such before the summit is reached, however, that the valley assumes an open alpine character, with scattered groves of larch (*Larix Lyallii*), and the slopes rising above it are there quite bare of wood. Near its mouth, the Cretaceous hills on the south are very high and irregular. Though the height of these hills and the bad weather prevailing at the date of our visit, prevented certainty in the matter, there is every appearance of a break in the main range in this vicinity, and it is possible that one of the larger tributaries of the Elk may rise to the east of the range. Beyond the position of this supposed gap, the limestone range to the south-west is very high and broken. At the summit of the pass, a high Creta-

ceous ridge intervenes between the stream and these mountains, while the bare limestone slopes of the Misty Range rise on the opposite side. Fragments of coal were observed in the stream a few miles south of the summit of the pass. On the night of the 16th of July, 1884, we experienced a heavy snow-storm in the pass, the snow being four inches deep the next morning.

Mist Creek.

Mist Creek, for six miles above the forks, runs in a straight north-west and south-east valley, receiving one large brook from the east and three or four from the west. In the lower part of the valley

Good timber.

and in the adjacent hills is a considerable quantity of good timber, consisting principally of spruce and black pine (*Picea Engelmanni* and *Pinus Murrayana*). This might be run down the stream at high stages of the water. The straight valley is eventually blocked by the fusion of the high Cretaceous hills which form the basal ridges of the Misty Range on one side, and the Highwood Range on the other. Turning abruptly to the west at this point, the source of the stream is reached in about a mile and a half, in a profound amphitheatre or cirque, at the base of the first-mentioned range. The floor of this amphitheatre consists of green, alpine meadows and slopes, with scattered clumps of Lyall's larch. Its elevation is 7,266 feet. As it proved impossible to go further in this direction, we returned down the valley to the point at which it bends, and climbing the bare ridge, found ourselves eventually on a narrow crest, at an elevation of 7,632 feet, with a practicable though steep and rough descent on the other side, to the valley of Sheep Creek.

FIG. 3. MIST MOUNTAIN FROM THE SOUTH.

Mist Mountain.

Mist Mountain, with an elevation of about 10,000 feet, is one of the highest summits in this region. It occupies a position of peculiar prominence, forming the prow-like, south-eastern extremity of the massive limestone range which separates Storm and Mist creeks. It is singularly bold and precipitous, and, as seen from the southward, rises in the centre of several high spurs composed of Cretaceous rocks, which surround it on three sides, and about their bare tops have a reddish

aspect which contrasts with the grey of the limestone cliffs of the culminating peak. To the north it attaches to other mountains of the range not much inferior in height, which, as they widen northward, become more or less separated into two parallel subordinate ridges, between which the furthest source of the Elbow River appears to rise. The Misty Range is exceedingly rugged and bare in its southern part, both on the side facing Mist Creek and that toward Storm Creek. The foot-hills of Cretaceous rocks lying between Mist Creek and the range, again show the remarkable comb-like structure previously alluded to, the ridges in this case are sharp-edged, with wide intervening valleys which have semi-circular outlines in cross section. This feature is illustrated in the accompanying plate, on which the ridges to the right and left of the view (with birds shown near them) are of Cretaceous rocks. Misty Range.

As already indicated, the head-waters of the Highwood proper, as well as those of the Cataract Branch, are included in the northern continuation of what may still be designated as the Crow Nest Cretaceous trough. Between the bounding limestone ranges, from the Highwood Gap to Mist Mountain, the Cretaceous rocks have a breadth of about six miles, and so far as observed in most places, maintain their usual westward dips. Further north, the trough is split into two long arms, the limestone mass of the Misty Range separating these. The western arm, or that occupied by the valley of Storm Creek, gradually narrows, and at the summit of the pass is only about a mile and a half wide. In the lower part of the valley, high Cretaceous ridges appear on both sides, but further up this valley, and down that which slopes toward the Kananaskis from the further side of the pass, there is but a single Cretaceous ridge, and this borders the western range. The Cretaceous rocks on this side of the valley dip at angles of 25° to 40° toward the limestones of the Elk Mountains, which may possibly rest upon them in the form of an overturned anticlinal. Those on the east side of the valley very generally dip eastward at rather low angles, and appear to abut against the nearly vertical limestones of the Misty Range along the line of a fault, as shown in the annexed diagramatic section. The extremity of this branch of the Cretaceous Bifurcation of Cretaceous trough. Rocks on Storm Creek.

FIG. 4. DIAGRAMATIC SECTION NEAR THE HEAD-WATERS OF STORM CREEK.

rocks seems to run out completely behind the range fronting on the Kananaskis.

Rocks on Mist Creek.

The Misty Range is with little doubt a great compressed anticlinal of limestone, overturned eastward. The evidence of this structure is perfectly clear on both sides of the cirque at the head of Mist Creek, where the Cretaceous shales and sandstones pass beneath the limestones at an angle of about 40°, and to the east of them are thrown into a series of overlapping folds, more or less fractured. This structure, as shown in the south side of the cirque, is illustrated in the accompanying cut, in which the rocks of the steep slope to the right are limestone. It is of interest in connection with the probable analogous crumpling of parts of the Cascade coal basin, further north.

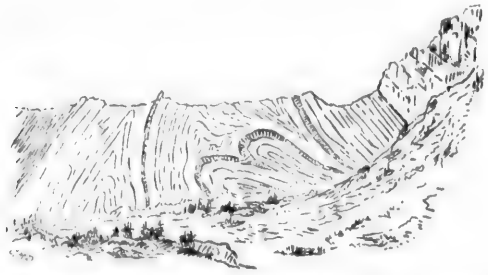

FIG. 5. OVERTURNED FOLDS OF CRETACEOUS ROCKS AT JUNCTION WITH LIMESTONE, MIST CREEK.

The western branch of the Cretaceous trough, along which Mist Creek runs, is still about two and a half miles wide at the source of the stream, and, as subsequently noted, runs up the valley of Sheep Creek nearly to the Elbow River.

Coal.

That coal occurs in greater or less quantity, pretty generally distributed throughout the Cretaceous rocks of this region, is evidenced by its constant appearance in the streams in rolled fragments. In addition to the places of such occurrence already noted, it was found in several small tributaries of Mist Creek. Seams a few inches thick, were seen in place in the ridges near the head of the creek, and more complete examination might lead to the discovery of workable deposits.

Head-waters of Sheep Creek and Elbow River.

Pass from Highwood to Sheep Creek.

In travelling northward in this part of the range, it was our object to fix the limits, as definitely as possible, and trace to its northern extremity, the great Crow Nest Cretaceous trough. Having been unable to secure the services of any Indian acquainted with the region, we were obliged to select for ourselves what appeared to be the best routes,

a circumstance resulting in some loss of time, and on several occasions causing us to fall into very rough, impracticable country. We had anticipated striking the Elbow River beyond the sources of Mist Creek, but on attaining the summit of the pass, saw at once that the headwaters of Sheep Creek were interposed. From this summit to Sheep Creek, a rapid descent of about 2,600 feet was effected, and the valley reached at a point at which it makes nearly a right angle, the upper part trending north-westward, parallel to the general direction of the mountains, the lower turning to the east and breaking across the outer range toward the foot-hills. From this point to that at which Mr. McConnell* examined Sheep Creek westward, in the foot-hills, a space of nearly twelve miles remains unexplored. The outer or eastern limestone range is here either much wider than usual, or there is an additional echelon range contiguous to it. A couple of miles below the point at which we reached the valley, is a mountain of which the northern side presents a remarkable, sheer cliff, about 2,000 feet in height.

Sheep Creek. Sheep Creek is here a rapid stream, about thirty feet wide by six inches or a foot deep. The valley is rather wide and flat bottomed, and rises pretty rapidly for five miles, till the source of the stream is reached, on a high plateau overlooking the deep, transverse valley of the Elbow River, at an elevation of 6,877 feet. The whole upper valley of Sheep Creek has been devastated by forest fires, which, in some cases have recurred till the trees have been entirely removed, grassy flats or slopes encumbered with stumps and fragments of burnt trees taking their place. In others, the blackened or bleached trunks are still standing, and the effect is desolate in the extreme.

Rocks on Sheep Creek. The limestones of the mountains on the north-east side of this part of the valley dip with great regularity to the south-westward, at an angle of about 40°, and the Cretaceous rocks are seen in one or two places to overlap them with apparent conformity. On the opposite side, the Cretaceous constitutes the foot-hills of the northern part of the Misty Range. At a distance of two miles from the Elbow River, the Cretaceous trough still has a width of nearly two miles, but between this point and the river, having now become a thin, superficial sheet, it bifurcates. The western branch extends to the edge of the Elbow Valley, and is evidently cut off by it, though there is some appearance of a very narrow fold of the same rocks engaged high up in the east side of the mountain to the north. Loose fragments of coal were seen in the bed of Sheep Creek, and it is of interest to note that it is here assuming an anthracitic character. Coal.

* See Report of Progress, 1882 84, p. 106 c.

Head of Elbow River.

The head-waters of the Elbow River occupy one of the remarkable valleys so frequently found in this part of the Rocky Mountains, which lie exactly at right angles to the trend of the constituent ridges and strike of the rocks. The valley in this case terminates abruptly about two miles west of the source of Sheep Creek, at the base of a very high and rough limestone range, which separates it from the Kananaskis. Two streams converge at this point. That from the south, which drains the central valley of the Misty Range, is evidently the larger. The second, coming from the north or north-west, is said by Indians to afford a rough pass to the Kananaskis. Below the junction of these two streams, the valley is remarkably wide and flat, and as seen from a height, contrasts curiously with the very rugged surrounding mountains by which it is almost enclosed. The scenery is grand, and would be beautiful, but for the fact that the forests have been almost entirely destroyed by fire. Ridges which appear to be moraines, occur in this part of the valley, and further down, glacial striæ were observed following its direction.

Valley of Elbow River.

The lower part of the valley is narrower than the upper, and a well-beaten, though rather rough and hilly trail leads down it, along the bank of the stream. The woods are in some places dense, and the mountains bordering it are often abrupt and cliff-like, though not remarkably high. About two miles before reaching the outer edge of the limestone range, a wide wooded valley opens southward, and from this point, that of the Elbow trends northward. The total length of the transverse valley occupied by the Elbow is about eight miles. At the eastern edge of the limestone ranges, where the stream issues into a low region among Cretaceous foot-hills, the river bed is nearly a quarter of a mile wide, and consists at low water, chiefly of dry, gravel bars. It is evidently subject to very heavy floods. The rocks forming the mountains on both sides of the portion of the Elbow above described, are, so far as could be observed, entirely of the great limestone series. At the point at which the trail from Sheep Creek reaches the Elbow, they dip south-westward, at an angle of about 40°, but flatten out further down the valley, and appear to lie in a series of light undulations with low dips. At the outer range they are again found dipping in the direction just noted, but at an angle of about 25°, and the first Cretaceous rocks seen to the east have a similar dip, and in the same direction. Whether this circumstance is here due to overturned folding, or to faulting, is uncertain. Three miles up the river from the western edge of the Cretaceous rocks of the foot-hills, exposures were found in the bottom of the valley of shales and sandstones which appear to belong to the Cretacous series. They are seen in the vicinity of the stream for about 300 yards, and may be more extensive, but are evidently confined to

Rocks on Elbow River.

Isolated Cretaceous area

the bottom of the valley. They probably constitute a small, isolated area, let in by faults, though it is just possible that the limestones of the mountains have been pushed eastward on a nearly horizontal thrust-plane over the Cretaceous. The evidences of enormous pressure from the westward, in this part of the moutains, would lead us to suspect the possible existence of such over-thrusts.

Outlying limestone area.

The eastern, or outer range of the mountains proper, is here the Fisher Range of Palliser's map. Beyond this, however, there is an outlying area of the Devonian or Devono-Carboniferous, limestone series, resembling an island in the Cretaceous foot-hills, but not much more rugged than these, nor very much exceeding them in height. The main stream of the Elbow cuts across this limestone area, and when, in 1882, Mr. McConnell followed up the Elbow for the purpose of defining the western edge of the Cretaceous rocks, he stopped at the outer or eastern edge of this area.* The northern and southern terminations of this limestone area, have not been accurately defined, but are, probably, nearly as shown on the map. Its greatest width is about four miles, and total length, probably, about fifteen miles.

Anticlinal structure.

The structure of this outlying area of limestone is very simple, being that of a broad, low anticlinal, in which the base-level of the Cretaceous rises above the plane of denudation. Where crossed to the north, on the Cañon Branch of the Elbow, it shows near the west edge a subsidiary synclinal which holds a narrow trough of Cretaceous rocks.

Fisher Branch.

For four miles beyond the point at which the Elbow crosses the eastern edge of the main limestone area of the mountains, it flows nearly due north in a wide valley with extensive gravelly flats. Near the point at which it again turns eastward and strikes into the outlying limestone area, it receives the Fisher Branch from the north. This stream is about equal in volume to that followed, and comes from the west of the outer ridge of the Fisher Range, which is here remarkably straight and rampart-like, and composed of limestones dipping south-westward at an angle of about 45°. Just below the Fisher Branch a second small stream comes in. This, when followed up, leads in about three miles to a summit with an elevation of 5,800 feet, after which a trail descends northward along another stream to a transverse valley which flows to the Cañon Branch, and after crossing a second small subsidiary summit, reaches the Cañon Branch itself. From this point, we were informed, a trail continues north-westward directly through to the Kananaskis. This trail evidently follows the Cretaceous trough intervening between the front of the Fisher Range and the outlying limestone area. On reaching the Cañon Branch, however, we

Detour by Canyon Branch.

* See section No. 1, facing p. 106 c, Report of Progress, Geological Survey, 1882-84.

followed it south-eastward and then southward back to the main Elbow River, at which point the Cretaceous rocks are again found overlying the limestones of the detached area, with eastward dips. The upper part of the limestone series is here formed of black, flaggy calcareous shales. These are overlain by Cretaceous sandstones, with a similar dip, and these again by a considerable thickness of dark Cretaceous shales.

Geological features.

The valley followed, between the outlying limestone area and the Fisher Range, is characterized by Cretaceous rocks, and is probably due to the existence of a considerable band of soft dark shales, which dip at an average angle of about 50° toward that range. Between these shales and the western edge of the outlying limestone area are sandstones and conglomerates, which weather rusty, and rest with an appearance of conformity on the limestones, with a dip of about S. 50° W. $<$ 30°. The subsidiary synclinal in the outlying limestone area, previously alluded to, holds a considerable thickness of sandstones, with some shaly beds of Cretaceous age. At the east edge of this trough, the limestones are again found dipping south-westward at an angle of about 40°, but further east gradually flatten out and then bend over to a north-eastward dip. The crest of this anticlinal nearly coincides with the highest part of the rather low, rounded mountains formed by the outlying patch of limestone. Before reaching the east edge of this limestone area, the stream flows for a mile through a remarkable Cañon, in which it is bordered by vertical walls of limestone, which, in some places are several hundred feet in height, and are continued above by rough and often nearly precipitous slopes to a greater elevation. It is necessary to travel in the bed of the stream, and at high stages of the water the route would be impassable. The river here appears, in its main direction, to follow that of a system of well-marked jointage-planes, which are frequently observable, and slope at a high angle to the northward.

Devonian fossils.

The lowest beds exposed occur at the west end of the cañon, and are rather soft, earthy and flaggy limestones holding numerous Devonian fossils. Amongst these are *Chonetes deflecta* and a second species allied to *C. scitula*, an *Orthis* like *O. Vanuxemi*, with two species of *Spirifera* and numerous remains of crinoidal columns.

The Kananaskis River.

Moraines and terraces.

The Kananaskis joins the Bow River at the eastern base of the mountains, making to do so a sharp northern bend. The two rivers are distant only four miles, at the points at which they respectively cross the eastern edge of the Palæozoic rocks. The most direct route from

Morley to the Kananaskis Gap, follows up Chiniquy Creek to the lake in which it originates, skirting the southern edge of the great depression of the Bow Valley. The hilly tract intervening between Chiniquy Lake and the Bow, evidently owes its character to the morainic accumulaions of glaciers which formerly debouched from the Bow and Kananaskis valleys, and is marked by low, gravelly and bouldery hills which project through terrace-flats of later origin. In the Kananaskis Gap, well-marked terraces appear on the sides of the mountains to an elevation of about 4,700 feet.

Character of the valley.

The valley of the Kananaskis differs from those of most of the rivers in the mountains, in the fact that it crosses the general direction of the ranges obliquely. In consequence of this, it is irregular in width, being in some places rough and narrow, in others wide and bordered by extensive terrace-flats. Its general course is nearly north-and-south, though with a decided convexity westward; its length, from its junction with the Bow to the Upper Lake, is about thirty-eight miles. Owing to comparatively recent forest fires, the trail is in some places much encumbered with fallen trees, and it has lost much of its old importance as an Indian route across the mountains. About its head-waters, the regularity of the constituent ranges of the mountains is somewhat interrupted, and a remarkable tract, of more than twenty square miles in area, occurs, which is characterized by terraces and low hills, but is surrounded on almost every side by high mountains. The elevation of this relatively depressed area is about 5,500 feet. It is continuous southward with the wide valley of Elk River, and to the north-north-westward with that leading to the Spray River. The want of continuity in the ranges above alluded to is, however, not due to any abrupt break, but rather to a hiatus left between several echelon-like over-lapping ridges.

Low area of country.

Rocks near Kananaskis Gap.

Geologically, the Kananaskis presents no features requiring very detailed description. The structure of the outer part of the mountains crossed by it, is shown on the eastern end of Section No. 2, on the face of the map. The Cretaceous sandstones and sandy shales, met with at the immediate eastern base of the mountains, dip S. 65° W. at angles of 30° to 45°, while the adjacent eastern outcrops of the limestones dip in the same direction at an angle of about 40°. This repeats the usual arrangement met with at the eastern junction of the Cretaceous and Palæozoic rocks, and is represented on the section as an inversion of the strata by folding, though it is possibly here brought about by faulting. From their eastern edge, the limestones, rising into high mountains, border the river for nearly eight miles; the dips being apparently all westward, and often at angles as high as 60°. The southern extension of the Cascade Cretaceous trough, which runs

Cretaceous rocks with coal.

across from the Bow, is then met with, forming a region of lower hills, and bounded to the west by high and rugged mountains attached to Wind Mountain.

It was intended to revisit and closely examine the Cretaceous rocks here, but this was not accomplished. The exposures of the rocks near the river are few, the valley being wide and trough-like. The Cretaceous rocks appear, however, to cross the valley obliquely and to terminate to the southward in the manner shown on the map. That their coal-bearing character, as developed on the Bow, continues, is evidenced by the occurrence of fragments of anthracite in the streams.

Kananaskis and Opal Ranges.

To the south-west of the Cretaceous area, the river occupies a valley bounded by the Kananaskis Range on the west and the Opal Mountains on the east. The rocks of both ranges dip westward, the former at angles of 30° to 40°, the latter at 70° to 80°, increasing southward, and in the vicinity of Tomb-stone Mountain becoming absolutely vertical and forming a very steep, rough-edged range. Both ranges appear to be composed chiefly of limestone, but the westward slopes of the Opal Mountains show a considerable thickness of brown-weathering quartzites, and these, or beds precisely resembling them from a distance, occur at the summit of the Kananaskis Range; giving reason for the belief that a fault, with eastward down-throw, runs along the valley separating the ranges. The throw of the fault must be at least equal to the height of the scarped eastern front of the Kananaskis, or about 4,000 feet.

Nearly on the horizon of the quartzites, but in limestones, on the west slope of the Opal Mountains, some fossils were found. The limestones at this place are much fractured and jointed and often weather to brown or reddish colors. Small cavities, lined with quartz crystals, occur both in these and the adjacent quartzites, and jointage surfaces are found, coated with films of opal, which, however, seldom shows the least play of colour. In one fragment of quartzite some obscurely preserved shells appeared, in which the original calcareous matter had been completely replaced by amber-coloured opal. The fossils mentioned are scarcely determinable, but represent a species of *Productus* and a *Strophomena* or *Strophodonta*, possibly Devonian. The nearly isolated mountain forming the northern end of the Opal Range is capped by dark crumbling beds which may possibly represent a Cretaceous outlier, and in the southern part of that portion of the valley between this and the Kananaskis Range, Cretaceous shales definitely occur, forming—as far as I have been able to ascertain—the extreme northern end of the Elk River Cretaceous trough.

Fossils.

It is probable that a considerable part of the low area about the head-waters of the river, previously mentioned, is underlain by Creta-

ceous rocks, but it is deeply covered by drift deposits and the outline given on the map is in consequence largely hypothetical. These rocks may even be continuous or nearly so with those, of which the existence is suspected in the valley between the Kananaskis and Spray Mountains, but this valley has not yet been examined. The actual mean surface of the country, in this part of the region, is nearly on the plane of junction of the limestones and Cretaceous rocks and it is, therefore, by no means improbable that a number of small Cretaceous infolds, the existence of which was not observed, may yet be proved. Probable limit of Cretaceous.

The Kananaskis Valley, just described, forms the eastern part of the pass of the same name, but from this point we turned southward, following the Elk River Cretaceous trough. A general description of the western portion of the pass, by Captain Palliser, may be found in his report (p. 94 *et seq.*) He describes the trail as rough, and even at the date of his journey, as being much encumbered by windfall. He also mentions having observed the appearance of clay-slates, replacing the limestones of the mountains, about half-way down the Palliser River, and it is probable that a somewhat extensive area of Cambrian rocks exists there. The height of the summit of the Kananaskis Pass, given on the map as 6,200 feet, is deduced from that observed by Captain Palliser, by adding the ascent recorded by him from the prairie east of the summit to the now more correctly ascertained height of the same prairie, and is probably nearly exact. The height on Palliser's map is stated as 5,700 feet. Western part of Kananaskis Pass.

Upper Part of the Elk River Valley.

The southern branch of the Kananaskis, and the Elk River, flow in opposite directions, from an open, swampy tract, which occupies a common wide valley. This valley has a nearly north-and-south course, and is one of the larger longitudinal valleys of the mountains. The height of the watershed at this point is 6,500 feet. Watershed.

The information gained respecting the upper part of the Elk Valley was obtained in 1884 by a journey made from the summit just referred to, southward to latitude 49° 49′, a distance of forty-seven miles. At the point last mentioned, we turned eastward by the North Fork Pass, leaving unexamined a length of about twenty-eight miles, to the north of Coal Creek. The traverse was made under unfavorable conditions, owing to bad weather and the great quantities of fallen timber which occur in many parts of this valley. We were obliged to cross to the west side of the river, by a swift and deep ford, and subsequently found much difficulty in recrossing to the east side, the river having become Difficulty of traversing the Elk Valley.

very high, owing to continued rains. An unsuccessful attempt was made at rafting, after which we were obliged to spend a couple of days in constructing a canvass canoe, by which we eventually made the traverse, near the mouth of the Fording River. These circumstances are here mentioned, in order to account for the rather disconnected character of the following notes.

Northern part of valley.

For twelve miles from the summit, the valley runs south-south-east, with an average width of about two miles, and makes a total gradual descent, in that distance, of about 1,000 feet. It is partly wooded, with patches of prairie, a few acres in extent, here and there, and is often swampy. The Elk mountains, about 9,000 feet high, form a continuous wall-like range on the left, and are composed of limestones and quartzites nearly on edge. From the limestone, *Spirifera Rockymontana* and a *Terebratula*, were obtained, the beds being apparently referable to the Carboniferous. The mountains on the right, are of about the same height, but much more broken in outline. Nearly opposite the summit, a tributary stream enters the valley from the west, which is larger than that occupying the main valley, and is reported by Indians to rise in a lake or lakes south of Mount Fox. It runs, for some distance, parallel to the stream followed by the trail and joins it about three and a half miles south of the summit. Five miles further on, a second large tributary enters from the same side, and the Elk becomes a considerable river, running with a very swift current, and milky from glacier-water derived from these western streams. The tributaries from the Elk Mountains are insignificant.

Termination of Elk Mountains.

The Elk mountains gradually decrease in height southward, and at the point previously mentioned, appear to terminate rather abruptly, a low, Cretaceous ridge, intervening between their southern end and the river. At the south end of this range, a torrent, twenty feet wide by one foot deep, comes in from the east. It is this stream which, it is suspected, may head east of the Elk Mountains in the Cretaceous hills adjacent to the Highwood (p. 97 B).

Elk Valley to mouth of Fording River.

From this point, the Elk flows directly south for over forty miles, following near the western edge of an important Cretaceous trough, the width of which increases suddenly from about two miles opposite the south end of the Elk Mountains to six miles or more; the newer rocks spreading eastward to the base of the High Rock Range beyond the end of the Elk Mountains. The river-valley is never less than two, and is in some places, three or four miles in width, with a flat bottom, which has been generally densely wooded with trees of good size; but these have in large part been destroyed by fire. The mountains on the west side continue high and rugged, and are chiefly composed of limestone, with westward dips at rather low

angles. Ten miles south of the termination of the Elk Mountains, a third important tributary falls in from the north-west, and the long, low mountain ridge, in the angle between this and the main stream, shows brown-weathering beds, with a similar dip, overlying the limestones. These are, with little doubt, quartzites of the kind previously described. To the east of the river is a region of broken Cretaceous hills and ridges, generally wooded, which intercept the view of the High Rock Range.

Fording River.

Finding the main valley almost impassable from fallen timber and swampy ground, we climbed the Cretaceous ridge nearly opposite the mouth of the tributary just alluded to, and after following it for some miles, descended eastward to the head-waters of the Fording River. This stream flows southward, parallel to the Elk, and in the same great Cretaceous trough, for over twenty-five miles,—nearly midway between it and the base of the High Rock Range, but separated from it by the Green Hills and continuing ridges.

Coal seams.

Occasional fragments of coal were observed on the gravel bars of the Elk above this point, but on reaching the upper part of the Fording River, so much drift coal was found in it, that half a day was devoted to tracing it up to the seams from which it was derived. The position of these is marked on the map. There are several thin seams at this place, the thickest observed being about two feet, but the exposures are not very good or extensive. The coal is bituminous and apparently of good quality, and occurs in association with shales and sandstones of the usual character. In these, a few fragments of fossil plants were found, resembling those elsewhere obtained in the Kootanie group, and including specimens of *Pinus Suskwaensis*. The dip is eastward at low angles; but it appears, from views of the High Rock Range, afterwards obtained, that the Cretaceous beds take a reverse inclination farther east, dipping westward from the flanks of these mountains.

Green Hills and High Rock Range.

After following the Fording River south-westward for a few miles, we crossed the Green Hills by a sort of pass, and again reached the Elk. The summit has an elevation of 6,226 feet, the hills above the notch by which it is crossed being several hundred feet higher. From this point, a very extensive view was gained both to the east and west, as well as down the Elk Valley. The country between the Green Hills and the High Rock Range is a mass of steep, Cretaceous hills, which reach an altitude, in some cases, of 7,000 feet or more, and are often bare and treeless about the summits and upper slopes. Where rocks come to the surface, they generally weather to reddish tints, and are easily distinguished from the more distant grey limestone peaks of the main range, of which they form foot-hills. The limestone ridge constituting the High Rock Range, is here narrow, but attains a height of at least

8,000 feet, and is marked by some conspicuous, bold peaks, one of which was recognized as having been seen in 1883, from the head-waters of the North-west Branch of the Old Man.

Mountains west of the Elk.

To the west, the range on the opposite side of the Elk is evidently almost entirely of limestone, which in places is nearly flat, but more generally has a low, westward dip. The front of the range here presents a series of rugged cliffs, broken at intervals by wild gorges, and is very high. Beyond it, however, the summits of a second and still higher and more rugged tier of mountains are seen, and in this, most of the streams flowing to the Elk head. It is probable that some of the highest peaks in this part of the Rocky Mountains will be found in this unexplored region west of the Elk River.

The Green Hills, where traversed, were found to consist of Cretaceous rocks with the usual characters, and with eastward dip, at angles of 20° to 40°. On the scarped, western side, not far from the summit, a coal-seam several feet in thickness was observed, but so much weathered and covered with rubbish that its precise importance could not be ascertained.

Greatest width of Cretaceous.

This northern portion of the Elk River Cretaceous trough attains its greatest width—about ten and a half miles—precisely on the 50th parallel. At the same point, the Wī-suk-i-tshak Range appears as a limestone ridge in the centre of the trough, and contrasts strikingly in its rough outlines and bare, rocky cliffs and slopes with the more rounded and generally wooded Cretaceous hills.

Elk River south of Fording River.

About seven miles north of the 50th parallel, the Fording River eventually joins the Elk, and here we left the Elk Valley, turning east by the North Fork Pass, previously described (p. 82 B). Several important streams reach the Elk from the west, within a few miles of this place, and up one of them, a trail is reported to run, which reaches the Kootanie east of Mount Sabine. A few miles south of the same point, the Elk turns more to the westward, and it must pursue a general course of about south-south-west to the mouth of Coal Creek, where the Crow Nest Pass reaches it. This part of the valley was reported to be at least as much encumbered with fallen timber as that which we had traversed.

Trees.

Larix Lyallii occurs as a straggling growth near the summit between the Kananaskis and the Elk. Further down the river, some fine groves of *Picea Engelmanni*, *Pinus Murrayana* and *Abies subalpina* were observed, and these trees constitute the greater part of the forest. The first Douglas fir noticed in the valley was at a point five miles south of the end of the Elk Mountains. Specimens of *Larix occidentalis*, of fair growth, first occur near the mouth of the Fording River, and the juniper was here observed to become arboreal in habit. The cedar

is reported to appear about five miles further south in the valley. It is abundant and large, as already mentioned, at the point at which the Crow Nest trail enters the valley. Birch trees of medium size were seen in the defile by which the Wi-suk-i-tshak Range is crossed, together with the little mountain maple (*Acer glabrum*). *Pinus albicaulis* occurs on the summits of the Green Hills, and probably elsewhere, at similar elevations. Notwithstanding the great areas destroyed by fire, there is still in the aggregate a large amount of fine timber in this valley, some spruce groves showing numerous trees which attain a diameter of three feet. The importance of this timber lies in the fact that the river affords a means of running it down to the Kootanie Valley. Timber.

The snow-fall in winter must be exceptionally heavy in the upper part of the Elk Valley. Evidence of a great depth of snow is afforded by the height at which branches have been broken by it, and the green, treeless beds of snow-slides appear on the mountains both to the east and west at innumerable points. Snow-fall

As will have been gathered from the foregoing description, the northern part of the Elk receives by far the greater portion of its water from the mountain region to the west of the valley.

The main facts in connection with the appearance and outlines of this part of the Elk River Cretaceous trough, having been given above it need only be added, that disregarding minor irregularities, of which, there are many, its structure appears to be synclinal, the axis of the syncline lying (between the Elk Mountains and the 50th parallel) to the east of the river. South of this point it becomes separated by the Wi-suk-i-tshak Range into two parts, which probably also have synclinal structures. The western edge of the trough is, however, probably defined throughout by a great fault or series of great faults, with eastern downthrow. No exact evidence of such faulting was gained, but none of the appearances elsewhere characteristic in the mountains, of overturned folding, were observed. Between the latitude of the Fording River and the Crow Nest Pass, the outlines given to the Cretaceous area are almost entirely hypothetical, and it may be regarded as quite probable that northward-running spurs extend into the mountains west of the Elk in this part of its course. A small Cretaceous outlier appears to occur high up in the limestone range to the west of the Elk, opposite the Green Hills, as indicated on the map. Elk River Cretaceous trough.

White Man's Pass and Sinclair Pass.

East entrance to pass.

Opposite Canmore station, on the Canadian Pacific railway in the Bow Valley, the entrance to the White Man's Pass (so-called by the Stoney Indians) appears as a remarkable notch in the front of the massive range which runs south-east from Mount Rundle. A mile and three-quarters from the Bow River, the base of the range is reached, and thence a rapid ascent is made of about 1,000 feet, the trail following the right bank of a little torrent, near which, about half-way up the ascent, a cave occurs.* The summit level is reached at a height of 5,300 feet, and here the valley followed by the trail becomes a narrow V-shaped defile, the bottom of which is encumbered with rocky *debris* from the impending mountains. The stream just referred to, flows out from beneath the loose material a short distance below the summit. On passing through the defile, the trail reaches a little flat meadow at its western embouchure, without making any appreciable descent, and joins the wide, longitudinal valley between the range just crossed and the Goat Range.

Valley between Goat and Rundle mountains.

The south-west side of Mount Rundle range, forming the back of the Three Sisters, and other peaks seen from the Bow, is largely composed of bare surfaces of limestone, dipping nearly at the angle of the slope, while the opposite front of the Goat Range repeats the precipitous and rough appearance of the corresponding aspect of the first-mentioned range. The longitudinal valley between them runs south-eastward for six and a half miles, and then south-south-west for six miles, there inosculating with that of the Spray River, at an elevation of about 5,260 feet. A short distance south from the opening of the defile, a watershed occurs in the valley, one small stream flowing in the direction just indicated, to the Spray, the other going north-westward and joining the same river after it enters this valley, by passing between the Goat Range and Terrace Mountains. The height of the watershed scarcely differs from that of the defile, and the valley throughout is rather wide and flat-bottomed, and filled more or less deeply with detrital materials. It is highly probable that the Spray, or some former representative of that stream, at one time flowed through this now abandoned valley from end to end.

Very high mountains.

Six miles south-east from the defile, the trail leaves the valley for some distance, and crosses a spur of the Goat Mountains, descending again to the border of Trout Lake, about two miles in length, which

* Of this cave the Indians tell some curious stories, but it is not extensive according to Mr. D. McDougall, who has examined it.

lies transversely to the general trend of the mountain axis, between the ends of the Goat and Kananaskis Ranges. From a point near the east end of the lake, a trail is said to run across the mountains to the Kananaskis River. The most prominent summit on the north side of the lake has an altitude of nearly 10,000 feet, while the highest peak to the south, surpasses 9,000 feet, and Wind Mountain, and another near it, attain 10,100 and 10,400 feet respectively, the whole combining to form a very rugged landscape, the higher parts of the mountains being nearly everywhere almost absolutely bare rock. In the longitudinal part of the valley, morainic ridges, more or less degraded, are abundant, and the lake is held in, either by material of similar origin, or by *débris* washed down from the mountains, there being no appearance of a rock-basin. The position of the part of the valley occupied by the lake is remarkable, as it cuts completely across what would otherwise be a continuous, high, limestone range. The whole valley, from the defile to the Spray River, has originally been well wooded, but most of the timber has been destroyed by fire, the fallen trees rendering the trail rough and difficult. In the longitudinal part of the valley, some patches of timber still remain unburnt. On the north side of the lake it has been completely destroyed, but on the slopes to the south, only about half has been burnt.

Trout Lake.

The geological features of the Bow Valley, near the entrance to the pass, are elsewhere described. The Mount Rundle range is formed of an anticlinal of limestone rocks, completely overturned to the north-eastward, as shown in figure 6 (p. 127 B). On the side of the range furthest from the Bow, these dip to the south-westward, at angles of 40° to 45°. The limestone rocks of the north-east side of the Goat Range, dip in the same direction, but at somewhat lower angles. On the south-west side of the same range, the dips become much higher, averaging nearly 60°. The attitude of the rocks, in this part of the pass, is shown in a general way on the eastern end of Section No. 2, but it is uncertain whether the Goat Range forms a second overturned anticlinal, or is separated from the first range by an extensive, longitudinal fault.

Geological features.

At the point above referred to, at which the trail passes over a spur of the Goat Range, a few fossils, which are referable to the Carboniferous were obtained in beds of hard grey, and reddish-grey, calcareous sandstone associated with the limestones. These include the pygidium of a *Proetus, Athyris subtilita* (?), a second form, allied to the same species, and a coral probably referable to the genus *Zaphrentis*.

Carboniferous fossils.

From Trout Lake westward to the Kootanie, the White Man's Pass runs nearly at right angles to the general trend of the mountains. At the point at which the stream from the lake reaches the Spray, the river makes a right-angled bend, and flows northward in the longi-

Wide longitudinal valley.

tudinal valley to the west of the Goat Range. This valley is continued southward between the Kananaskis and Spray Mountains, and carries a small tributary to the Spray, which must rise near the source of one of the branches of the Kananaskis River. A trail is also reported to run up the valley to the Kananaskis. The northern part of this longitudinal valley, is a wide, straight, flat-bottomed depression, of the usual type. Its continuation to the southward is, however, nearly twice as wide, exclusive of an area of hills and ridges, which occupy a part of the low area, and attach westward to the Spray Mountains.

Fall.

A mile and a half above the point at which the Spray turns northward it forms a picturesque fall, about forty feet in height, over pale-grey limestone rocks. The trail, then following the north-bank of the river, through green woods, passes between the north end of the Spray Mountains and Cone Mountain,—the latter, a sharp, symmetrical peak, composed of vertical beds of limestone, with a conspicuous, oblique fissure on the south side. West of Cone Mountain, a tributary about equal in volume to the main stream, joins from the north. A well-marked trail runs up its valley, and is reported to join the Simpson Pass, east of the main watershed. From this point the main stream turns southward, occupying another longitudinal valley to the west of the Spray Mountains, up which a second Indian trail to the Kananaskis runs. About four miles to the south, the Spray Mountains culminate in a remarkable, pyramidal peak.

Spray Mountains and Cone Mountain.

The Blue Mountains.

Turning southward from the mouth of the tributary, just mentioned, the trail is at first rough, passing over a surface of limestone rocks; it then traverses prairie patches and open woods, passes the entrance of a deep and picturesque valley, in the Blue Mountains—here the watershed range—and reaches the base of the same range at the mouth of a second valley of the same character. This carries a small tributary stream, in following which a pretty steep ascent is first made to a deep, narrow valley, with sub-alpine vegetation and occasional open meadows. The stream enters the head of this valley from the southward, coming from a gorge which separates the high, bare outer ridge of the range from the summit elevations. From the bank of the stream, a rapid ascent is made, by a series of steep zig-zags, near the small torrent, which dashes down over limestone rocks, and the actual summit reached, at an elevation of 6,807 feet. The summit is here found in a wide, irregular, open valley, which supports a scattered growth of stunted and wind-lashed trees. A small lake feeds the torrent just mentioned.

Limestone series.

The rocks seen along the part of the pass just described, are all referable to the great limestone series, and in Cone Mountain and the Spray Mountains, are almost absolutely vertical, and may be considered as forming a continuation of the similarly characterized western ridge

of the Saw-back Range to the north. It is not improbable, however, that the valleys to the east and west of the Spray Mountains may hold infolds of Cretaceous rocks, as previously indicated in connection with the Kananaskis (p. 107 B). The culminating peak of the Spray Mountains shows a high spur on its west side, between which and the apex, is seen a narrow fold of vertical, dark-coloured rocks, which are almost certainly Cretaceous. At the eastern base of the Blue Mountains, the limestones appear to dip south-westward, but further up toward the summit, have a general tendency to dip to the north-east, though often wildly contorted and exhibiting a series of large, parallel corrugations. The actual summit appears to coincide with a well-marked anticlinal axis, which runs with the range. On the east side, the limestones are nearly vertical, but turn over and dip at low angles south-westward on the opposite slope. Some red beds appear near the summit, which may possibly represent the Triassic rocks seen further southward.

Cretaceous rocks.

Rocks at the summit.

From the summit, the Cross River is followed down to the Kootanie. This stream is called Tsha-kooap-tē-ha-wap-ta, by the Stoneys, and its name alludes to the circumstance related by them that some early traveller set up a cross in the pass, not far from the summit.* From the summit, the stream descends very rapidly to the south-westward, in a narrow rocky valley, shut in by high and rough mountains, falling about 2,300 feet to the mouth of North Creek, at which point its elevation is 4,471 feet. North Creek and other tributaries received in this part of its course have the character of mountain torrents. Half-way between the summit and North Creek, a high, rocky valley opens southward, which towards its head holds masses of glacier-ice, and shows a number of small cascades. After breaking through the next range to the westward, the Cross River flows northward for a couple of miles, in a narrow, wooded, longitudinal valley, and before again turning west, joins a stream of about equal size,—the North Fork,—derived from the northern and wider continuation of the same valley. To this point the descent of the river continues very steep, and it shows numerous little cascades and rapids, the clear blue water having carved its bed in white marble. It next flows westward for about seven miles, in a wide and flat valley, characterized by extensive gravel bars and numerous sloughs and flood-channels, and precisely resembling the corresponding portions of the Kicking Horse and Vermilion valleys. Before reaching the Kootanie, it again

Descent westward.

* Since the above was written, I have had an opportunity of referring to De Smet's *Oregon Missions* (New York, 1847). De Smet in his Missionary Journey of 1845 evidently traversed what is now named the Sinclair Pass. He subsequently mentions the "Vermilion River," as on the approach to the watershed, but this name is probably not applied to the same stream now so-called. He describes the erection of a cross at the point at which he traversed the watershed (p. 144), and this fact, taken in connection with the Indian tradition above referred to, and the context of his narrative, render it almost certain that he crossed to the Bow River by the White Man's Pass.

changes its direction to southward, flowing past the long, sloping, wooded end of the Mitchell Range. The trail there leaves the river, cutting across a spur and reaching a ford of the Kootanie at an elevation of 3,440 feet.

Rocks on west slope.

From the immediate vicinity of the summit of the pass, westward to the mouth of the North Fork, the limestones, both in the bottom of the valley and so far as could be observed, to the tops of the adjacent mountains, have become changed to marble, which is in some places very

Marble.

coarsely crystalline. In colour, the marble generally varies from white to yellowish shades, but blotched grey and white, and brown and white varieties were also observed. More or less pyrites and grains of magnetite are generally disseminated through the rock, and in all the

Vein matter.

streams a great abundance of crystalline vein-matter, calcareous, dolomitic, or silicious, was noticed. Though no metalliferous minerals of value were observed, this appears to be a locality worthy of the attention of the prospector, on account of the extent and character of the local metamorphism. In no other place in the mountains were the

Cause of alteration of rocks.

limestones observed to be altered over so extensive an area. The cause of the alteration is obscure. It is accompanied by no evidences of special mechanical violence, as the beds west of the summit dip southwestward at low, regular angles, nearly equalling that of the slope of the valley, and further down, becomes nearly horizontal, or show very light north-easterly dips. There is reason to believe, however, that an intrusive mass, resembling that subsequently described, (See also p. 122 B) may here nearly approach the surface, though it has not actually been exposed by denudation.

Rocks west of North Fork.

In about four miles below the mouth of the North Fork, the wide valley cuts through two mountain ridges, which together show a general synclinal structure. At the western edge of this syncline, however, a a narrow anticlinal, bodily overturned to the eastward, was observed far up in the mountain range, opposite the mouth of the North Fork. The rocks of this part of the valley seem to belong, chiefly, or entirely, to the limestone series, though their broken and jointed character rendered it difficult to distinguish the nature of the beds in the mountain sides.

Diorite.

At the mouth of the second tributary below the North Fork, on the same side, are numerous large masses of greenish-grey diorite (?), somewhat resembling the intrusion of Ice River (p. 122 B) but apparently not, like that, a nepheline-syenite. These have been derived from an intrusion of the same material, against which the limestones rise to an angle of 45°, and form the steep, western edge of the synclinal just mentioned. The area of the intrusive mass may be extensive to the north of the valley of the pass. Associated with, and cutting the diorite, are quartz veins, carrying copper pyrites, but on assay by Mr. Hoffmann, these proved to contain neither gold nor silver. The vicinity

of this intrusive mass, however, is one to which the prospector might devote attention with some probability of good results.

Cambrian rocks

Beyond the stream near which this intrusion occurs, the main valley becomes floored by slaty rocks, which vary from nearly black to grey in colour, and are generally glossy and usually rather soft. The bedded structure has been almost entirely obscured by cleavage, but the slates are often more or less calcareous, and from the appearance here and also at some places near the bases of the mountains further up the valley, there is reason to suspect a passage of these into the overlying limestones, with possible conformity. The circumstances in this connection repeat those elsewhere noticed on the Kicking Horse, and the rocks are very similar in appearance.

The spur forming the termination of the Mitchell Range is again composed of the usual grey massive limestone.

Upper Kootanie Valley.

The Sinclair Pass forms a direct western continuation of the White Man's Pass, and affords a cross section of the western range of the Rocky Mountains, which appears under the name of the Brisco Range to the north, and the Stanford Range to the south. The Upper Kootanie Valley has been mentioned in the introductory part of this report as one of the most important in the mountain region. It is here about three miles in width between the slopes of the adjacent mountains. Its surface is formed chiefly of terrace accumulations, and is generally wooded, scarped banks here and there along the river showing white silts with interbedded gravels like those elsewhere described (p. 30 B). The ford is a good one at low water, but it would be impassable when the river is in flood.

Sinclair Pass.

The range crossed by the Sinclair Pass has a width of about nine miles only. The valley traversed by the pass is not structurally a very important one, being rather narrow, particularly about the summit. The trail is rough, crooked, and in places very stony, following in some places the bottom of the valley, in others climbing far up the steep slopes. On the east side, the timber has not been extensively destroyed by fire, but it is nearly all burnt on the western slope in the valley of Berland's Creek. The range crossed, is found to consist of at least, three subsidiary mountain ridges, but the intervening valleys are narrow and not very definitely continuous. The summit, with an elevation of 4,662 feet, is reached at three miles from the eastern base, and Berland's Creek, flowing westward, heads in a pool or small lake, which is evidently held in by an accumulation of *débris* washed into the valley from the adjacent mountains. Where it cuts through the western mountain ridge, the stream flows for over a mile and a half in a very deep, narrow gorge, after leaving which, it cuts for itself a wider, but still deep valley in the high gravelly and silty terraces of the

Berland's Creek.

Columbia Valley. The cedar grows in the pass from the summit to the western base of the range. The birch and shrubby maple (*Acer glabrum*) characterize the pass throughout, together with the Douglas fir, Engelmann's and the balsam spruce and the black pine. *Fatsia horrida* is found about the summit.

Vegetation.

Rocks on Sinclair Pass.

The Cambrian rocks, which are supposed to underlie the flat valley of the Kootanie, were not seen on this traverse, and the rocks of the mountains between the Upper Kootanie and the Columbia, appear to be all referable to the limestone series. These, in the eastern ridge of the mountains, form an anticlinal, but westward, are almost everywhere on edge. Near the middle of the gorge, the cliffs assume a bright red colour, and from the Columbia Valley, the same red zone may be traced for several miles along the front of the mountains, apparently nearly following the strike of the vertical rocks. On examination, the red rock is found to be in general completely shattered, and generally more or less porous and cavernous, though re-cemented by calcareous matter. This shattered zone appears to have formed a conduit for mineral waters, which may possibly have been thermal and the coloration has been produced, either by the deposition of iron by these waters, or by the peroxidation of ferruginous minerals already present. Sir George Simpson's description of this pass has already been referred to (p. 10 B).

Reddened limestones.

Simpson Pass.

This, as previously stated (p. 9 B), is the pass followed by Sir George Simpson to the Upper Kootanie Valley in 1841. By the Stoney Indians it is known as the Shuswap Pass. It leaves the Bow River at a height of about 4,500 feet opposite Hole-in-the-wall Mountain, to the west of Bourgeau Mountain, and follows Heely's Creek to its source, crossing the watershed at a height of about 6,650 feet, at a distance by the valley of nearly nine miles from the mouth of the creek. The head waters of Simpson River are here found to the east of the range which, further north, constitutes the summit ridge. The descent on the the west side is steep, amounting to about 1,900 feet in five miles. About eight miles further on, the trail joins that of the Vermilion Pass at the confluence of the Simpson with the Vermilion River, at a height of 3,932 feet. This pass was examined by Mr. R. G. McConnell in 1885.

The Vermilion Pass.

Pass in the Bow Range.

Like the White Man's Pass, Simpson's and Kicking Horse passes, the eastern approach to this route over the watershed is formed by the great valley of the Bow. The trail leaves the Bow opposite Silver City, at an elevation of 4,624 feet, and reaches the summit by following Little

Vermilion Creek to its head, in a distance of six and a half miles, the summit elevation being 5,264 feet. From the summit, the valley of the pass continues exactly transverse to the Bow Range for six miles, when it joins one of the more important longitudinal valleys of the mountains, and bends through a right angle to a south-eastward course. The height of the river at this bend is 4,523 feet. As pointed out by Dr. Hector, who first examined this pass, it is exceptional in the near equality of its grades on both slopes.

Summit lakes.

The north-eastern front of the Bow Range is abrupt and wall-like, the pass entering it by a deep notch, in the eastern opening of which is a little lake about half a mile in length. This is connected by a stream, with a still smaller pool, which practically occupies the summit, though the ground rises slightly for a short distance beyond its head. Less than half a mile further on, a milk-white torrent, forming the source of the Vermilion River, and fed by masses of glacier ice in the southern end of the Bow Range, enters the pass. The valley, however, continues to be narrow, and in general, densely wooded as far as the bend.

Rocks of Bow Range.

The north-eastern escarpment of the Bow Range, at the entrance of the pass, appears to be entirely composed of quartzites and slaty rocks, referable to the Cambrian, with persistent, light, south-westward dips, at angles of 20° to 30°. Shortly after entering the pass, however, the overlying limestone series appears, forming the summits of the mountains; and owing to the dip, gradually descends in their slopes, till it reaches the bottom of the valley about three and a half miles westward. It is shortly, however, again replaced in the mountains near the bend, by the slaty and schistose rocks, which dip south-westward, at an angle of about 40°. The mode of junction of the limestones with these rocks, on the west side, was not here observed. The total thickness of quartzites and slaty rocks, referred to the Cambrian, exposed in the north-east side of the Bow Range must approach 5,000 feet. The rocks exposed near the second little lake, at the summit, are probably about 2,000 feet below the base of the limestone series, and in these, on the 6th of August, 1884, the first fossils found by us in place in the rocks of this series were obtained. These consisted of two rather obscure impressions of trilobites, one of which has, however, been definitely recognized by Prof. C. D. Walcott as *Olenellus Gilberti*. Careful search failed to bring to light any other forms in this place, but annelide burrows abound, both vertical and horizontal, (often filled with quartzite in the case of the schistose rocks,) together with various more or less obscure tracks and markings. The rocks themselves are here whitish, grey and pinkish quartzites, in which broken fragments of red shale are frequently imbedded as pebbles, as previously noted on the South Kootanie Pass. With these are interbedded grey and blackish, schistose argillites, which are not cleared.

Cambrian.

First Cambrian fossils.

Chalybeate springs.

The Vermilion Pass takes its name from the existence of considerable deposits of ochre on the river-flats, about six miles west of the summit, near the place previously alluded to as the bend. These are produced by very copious chalybeate springs, which flow out in the gravel, and may some day be utilized medicinally. The ochre is naturally yellow, but the Indians cause it to assume a red colour by burning it.

Near the bend, a couple of large streams enter from the mountains to the westward, and the river more than doubles its former size. The valley of one these streams appears to correspond with the longitudinal valley occupied by the Otter-tail farther north, with which it is, very probably, continuous.

Vermilion River valley.

From this point the Vermilion flows south-westward, fifteen miles, in a valley which at first averages about a mile in width, but becomes much wider where it is joined by the Simpson River. This portion of the valley presents no features of particular interest. The Vermilion Range, to the south-west, has a synclinal structure; the axial summits, which reach elevations of about 9,000 feet, are nearly three miles back from the valley, the intervening space being occupied by buttress-like spurs, attaching to the central mountains, but separated from each other by a number of deep, rough narrow valleys. These spurs appear to be entirely referable to the Cambrian series, and to consist chiefly of schistose or slaty rocks, with persistent, south-westward dips, at an angle of about 30°. The axial mountains are evidently of limestone. On the opposite side of the valley, the bordering mountains are more rounded in form, and glimpses can only occasionally be caught of higher and rugged peaks further back, toward the watershed range. The river for a number of miles nearly follows the strike of a band of yellowish-gray, glossy slates and schists, which often hold little nodules of pyrites, and resemble those seen near Boulder Creek on the Kicking Horse. Grey and black, distinctly argillaceous and often, calcareous slates, also occur, in which the cleavage cuts the bedding at a high angle. The cleavage-strike at one place was observed to be N. 65° W., with dip at an angle of 45° southward. Large pebbles of diorite or nepheline-syenite, in the river, appear to indicate, either that the intrusion of rocks of this character, seen on Ice River (p, 122 B), extends to some of the sources of the Vermilion, or that another similar intrusion occurs within its drainage area.

Cambrian slates.

Pass in Vermilion Range.

Turning westward again at a right angle, from the mouth of Simpson River, the Vermilion cuts through the mountains, which separate it from the upper part of the Kootanie, and, in about seven miles, joins that river at an approximate elevation of 3,800 feet. The river runs for part of this distance in a narrow gorge, while the trail, following the

hill-side to the north, is very rough and bad. On approaching the limestone which forms the central mountains of the Vermilion Range, the slaty rocks become bluish in colour, and occasionally hold beds of hard, blackish-blue limestone, giving rise to the same appearance of a passage between the series, as occurs near the mouth of the Beaver-foot. On the north-east side of the synclinal, the limestones dip at first at angles of 40° to 45°, but westward, become in this place nearly vertical. The axial mountains, on both sides of the gorge, are very steep and bold.

Timber.

The forest in the Vermilion Valley has been comparatively little destroyed by fire, and there are some areas of timber of very fair quality, both on the slopes of the mountain and to the north-east of the valley above the mouth of Simpson River, and in the narrower part of the valley below that river.

Head-waters of Kootanie and Beaver-foo

The Vermilion River is nearly twice the volume of the Kootanie at their point of junction, and might, in consequence, be regarded as entitled to bear the latter name; but the circumstance that the Kootanie occupies the larger and more continuous valley, induced Dr. Hector to name these streams as they now appear on the map. The valley of the Kootanie is continued north-westward by that of the Beaver-foot, to the angle of the Kicking Horse River, and between the Vermilion and Brisco Ranges, has an average width of nearly four miles, resembling—though on a somewhat smaller scale—that of the parallel portion of the Columbia. Up to the summit between the Kootanie and Beaver-foot, the valley is generally wooded, and contains some good timber, though with occasional open meadows and little prairies. The water of the Kootanie is clear, and the current rather swift, though much less so than the Vermilion. The river follows a tortuous course in a trough-like depression in the centre of the valley, about three-quarters of a mile in width, and bordered by gravelly terraces, which run back to the bases of the mountains on either side. The rise in the valley from the junction of the two streams to the summit above referred to, is about 338 feet, in a distance of seventeen miles, the summit elevation being 4,158 feet. The summit is swampy, and Dr. Hector describes the Kootanie as rising here in two small lakes, which, as we kept close to the base of the mountains to the east, we did not see.

Rocks.

The rocks seen along the upper part of the Kootanie are rather soft, grey or yellowish, silvery slates. These or similar Cambrian rocks appear to occupy the whole width of the valley, and also to constitute all the lower hills of the Vermilion Range. The central mountains of this range are very bold and steep, reaching heights greater than 9,000 feet, and being apparently still composed for the greater part of limestone. The Brisco Range, on the opposite side of the valley,

appears to be throughout this part of its length entirely of limestone, which at first has persistent low westward dips, but toward the Kootanie-Beaverfoot summit becomes in some places more disturbed and nearly vertical.

Beaver-foot River.

The Beaver-foot rises in the mountains to the north-east of the wide valley, just beyond the summit, and after flowing north-westward in the valley, twelve and a half miles, reaches the Kicking Horse at its angle. Where it enters the valley it is a swift stream, about thirty-five feet wide by six inches deep. About four miles further on it is joined by Ice River,* which is about equal in size. The part of the valley occupied by the Beaver-foot is not so wide and parallel-sided as that holding the Kootanie. The original forest has in most places been replaced by second-growth woods, including much aspen, though belts of good spruce timber still exist in places, particularly along the banks of the river. The valley is generally marshy near the river, and at the sides bordered by irregular gravelly terraces.

On approaching the Kicking Horse, the Beaver-foot Range, forming the south-west side of the valley, becomes bordered by rounded and wooded hills, composed of slaty Cambrian rocks, and rocks of the same kind underlie the valley, as far as observed.† The centre of the high range on the opposite side of the valley, however, is here formed of an important mass of intrusive syenitic rocks, which were examined on Ice River, where they are extensively developed.

Ice River.

The valley of Ice River runs northward for about seven miles into the heart of the Otter-tail Mountains, between Mounts Vaux and Goodsir, of Hector, and terminates at the base of a high narrow range which separates it from the Otter-tail Valley. It is deep and narrow, being closely hemmed in by the neighbouring mountains, while the stream itself is a mere torrent, often encumbered by masses of rocks from the rough mountain slopes. The mountains at the head of the valley are covered with glaciers, one of which shows, from a distance, a cliff of solid blue ice which is probably several hundred feet in height.

Important intrusive mass.

The intrusive mass above alluded to, is first seen on Ice River about two miles up the valley from the south-western base of the mountains at its entrance. The mountains on the east side of the valley are here composed of this syenitic rock for their whole height. Further up it

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* *Wash-ma-woop-ta* of the Stoneys.

† Dr. Hector, who followed the route here described, writes:—"In the bottom of the valley we passed several masses of true gneiss with one or two greenstone dykes." (Journals, Detailed Reports and Observations Relative to the Explorations by Captain Palliser, etc., p. 105). It is, therefore, probable that crystalline rocks like those of Ice River may occur also in some places near the Beaver-foot, but none of the rocks seen by us could be described as true gneiss.

forms the entire mass of the mountains on the opposite side of the valley, and apparently also of those at its head. Southward, the same mass continues at least as far as the head of the Beaver-foot, where it is again seen constituting the axial mountains of the range. Its termination in this direction has, however, not been defined, nor has the western edge of the mass been outlined. Its extent and character deserve further investigation, as its occurrence is correlated with the appearance of much vein matter in the neighboring rocks, and very probably with the metalliferous deposits now being prospected on the Otter-tail River.

Junction of Igneous rocks with Cambrian.

The circumstances connected with the contact of this intrusive mass with the slaty Cambrian rocks on the Ice River, show that it is newer than these rocks, but older in date than the cleavage which has since affected them, and which is probably referable to pressure in connection with the main period of mountain upheaval. The mass may in part break through the Cambrian, but it has also forced the rocks of that formation upward, causing them to dip away from its flanks. Near the mass, these elsewhere slaty rocks lose all appearance of cleavage, and though plainly showing their original bedding, are baked and porcelainized. They are generally grey to black in colour, though in some cases nearly white, and form a hard petrosilex, which rings under the hammer.

Character of intrusive mass.

The intrusive mass itself, though very varied in appearance in different places, is, in the main, a nepheline-syenite. The form most abundantly represented is a medium- to coarse-grained crystalline rock, composed of felspar, nepheline and hornblende in varying quantities, with grains of magnetite and some crystals of sphene. The colour generally varies from pale- to dark-grey, becoming nearly black in some places, when the hornblende greatly preponderates. In such black varieties sphene is particularly abundant. The crystals of the component minerals are occasionally nearly an inch in length, while in rare instances they become almost cryptocrystalline. Other specimens derived from the same occurrence, but found as boulders in the bed of the torrent, have a banded and almost gneissic aspect, and under the microscope prove to contain numerous grains of quartz. A material of this character is probably that to which Dr. Hector has referred as gneiss, but there is no evidence of its sedimentary origin.

Its structure.

As far as I was able to determine, the mass appears to have been much disturbed, and, as it were, kneaded together while in a plastic or semi-plastic state. Portions of it have become brecciated, and are re-cemented by similar material, differing only in texture or colour. Veins and crevices, which have evidently been filled by segregative action, also occur, and in these, minerals similar to those composing the main mass are developed; but with them, in considerable abundance,

sodalite of a beautiful ultramarine-blue colour is found. In the same veins crystals of ilmenite were observed. This mineral has been subjected by Mr. C. Hoffmann to a rough quantitative analysis, and found to contain titanium dioxide, 47·5 per cent.; iron, equal to 39·8 per cent. of ferrous oxide, with 6·5 per cent. of manganese. No other constituents were sought for, and the specimen included a small percentage of gangue. The large proportion of manganese is very remarkable.

Ilmenite.

Sodalite.

The sodalite has been analysed by Dr. B. J. Harrington, who describes it in the Transactions of the Royal Society of Canada, Vol. IV., Sect. IV. It much resembles lapis lazuli in appearance, and would have considerable value as an ornamental stone. It is not confined to a single part of the intrusive mass, as it was found also to occur in fragments brought down from the mountains further south, in the bed of the Beaver-foot, and closer search than we were able to make would probably lead to the discovery of even larger pieces than those we obtained, some of which are several inches in diameter.

Drift fragments of intrusive rocks.

Intrusive rocks are of such rare occurrence in this part of the mountains, and the appearance of those here met with is so characteristic, that detached fragments at once catch the eye. The occurrence of such fragments on the Vermilion, below the bend, has already been noted, and its significance alluded to. Small pieces of the same rock were found in the Kicking Horse above the mouth of the Beaver-foot, and apparently show that some similar intrusive mass occurs on its head-waters or those of the Otter-tail. A few well-rounded pieces of the same material were found in 1883 in the Columbia-Kootanie valley south of the lakes. It is uncertain whether these were carried to their present position by the Vermilion and Kootanie Rivers, at a former period, or by a southward movement of ice during the glacial period. The latter supposition appears the most probable, as the fragments occurred on a terrace at some height above the present stream.

Bow Valley.

Account here given merely preliminary.

The character of the portion of the Bow Valley within the mountains has already been described in general terms (p. 27 B). It is of particular interest as being the route adopted for the railway which now renders it readily accessible to every traveller. The geological features of the Bow and Kicking Horse valleys were, however, not more closely investigated than those of other parts of the extensive tract of mountains here reported on, and as Mr. R. G. McConnell is at present engaged in supplementing such reconnaissance work by a special and thorough

examination of these particular valleys, the results of which will soon be prepared for publication, it is considered unnecessary here to enter into any lengthened description of my own preliminary work. An exception is, however, made in the case of that part of the Bow Valley which includes a portion of the Cascade Cretaceous basin. This, on account of its important occurrences of anthracite, has been surveyed in detail, and is here treated at some length and illustrated in the accompanying special map. With this exception the following notes must be considered as of a strictly preliminary character.

Bow Valley in foot-hills.

To the east of the mountains the Bow River flows in a great valley, from four to five miles in width, which crosses the general direction of foot-hills exactly at right angles. The general appearance of this valley near the base of the mountains is illustrated in a previous report.* For a width of twenty miles east of the base of the mountains, the Cretaceous rocks are here thrown into a series of parallel and often compressed plications, the intricacies of which yet remain to be worked out, and the rocks are often for considerable distances nearly vertical. At the base of the mountains, however, these beds are found to lie at comparatively low angles, and to show a nearly uniform dip toward the outer limestone range, beneath the rocks of which they appear to pass in consequence of the existence of an overturned anticlinal fold, which is possibly also accompanied by faulting.

Lower part of valley in mountains.

The limestone of the mountains, though it extends further to the east in the mountains to the north and south, is first met with in the valley about half a mile above Kananaskis station, at the place formerly known as Bow River Gap. The rocks at this point have been heavily grooved and striated by the great glacier, which evidently at a former period debouched by the Bow Valley into the foot-hill region. From this place, for six miles, the valley is rather narrow, and is transverse to the direction of the constituent ridges of the mountains, which abut upon it boldly, and are composed chiefly of limestones, with persistent westward dips, generally at rather high angles. To the north, the mountains form part of the Fairholme Range, while the highest summit to the south was named Pigeon Mountain by Bourgeau. This part of the valley is generally wooded, and a couple of small lakes occur in it, which were named *Lacs des Arcs* by the same member of Palliser's expedition. Just west of the second and smaller lake the old trail climbed a steep limestone spur from the mountain to the north, from which a fine view of this noble entrance to the mountain country is obtained. The mountain to the north of this spur is that named Grotto Mountain, also by Bourgeau.

* Report of Progress, 1882-84. Plate facing p. 30 c.

Wide longitudinal valley.

Beyond Grotto Mountain, a wide, longitudinal valley is entered, and this is occupied by the Bow for a distance of nearly fifteen miles to the north-westward. It averages about four miles in width, and is bounded on one side by the western ridge of the Fairholme Mountains, on the other by Wind Mountain and the range connecting it with Mount Rundle, which, further north-westward, is continued by Cascade Mountain. This wide valley is generally floored by shingly terraces, and is largely wooded, though also containing a number of little prairies. Canmore Station is situated on one of the largest of these, which was formerly known by the Stoneys as "The prairie where they shot the little pine." Near the point at which the course of the Bow again turns to the west, it receives an important tributary—Cascade River,—which occupies the same longitudinal valley still further to the north-westward. Not far from this point, at the southern base of Cascade Mountain, is Banff station. The height of the surface of the Bow above sea-level in this part of its course is about 4,300 feet.

Cascade Coal Basin.

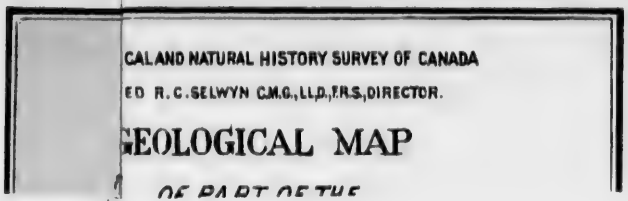
Important coal-bearing region.

The most interesting and important circumstance connected with this part of the Bow Valley is the fact that it is underlaid throughout its length by Cretaceous coal-bearing rocks of the Kootanie series. The coal, which is an anthracite, was first discovered, I believe, in 1883. It is now being opened up, and promises to be of considerable importance on account of its position on the railway line, and its excellent quality. The special map accompanying this part of the report has been prepared to show the distribution of these economically important coal-bearing rocks, which are here described at some length. In this description, in addition to the facts observed by myself in 1883 and 1884, the result of investigations since made by Mr. McConnell in the region represented by the south-western part of the map, is included. The two lower sections shown on the map are by Mr. McConnell, and give a clear general idea of the structure of the entire width of the Cretaceous trough.

Observations by Mr. McConnell.

Dimensions of the basin.

This particular infold of the Cretaceous rocks has already been referred to as having been met with on the Kananaskis River (p. 105 B). It has been named the Cascade basin or trough, from the fact that it runs for a long distance to the north-westward in the valley of the stream so-called. It differs in character from the other areas of Cretaceous rocks found within the mountains, chiefly in the fact of its great length as compared with its width, and the circumstance that the alteration of the contained coal beds has here gone so far as to result in the change of the coal into an anthracite. From its south-eastern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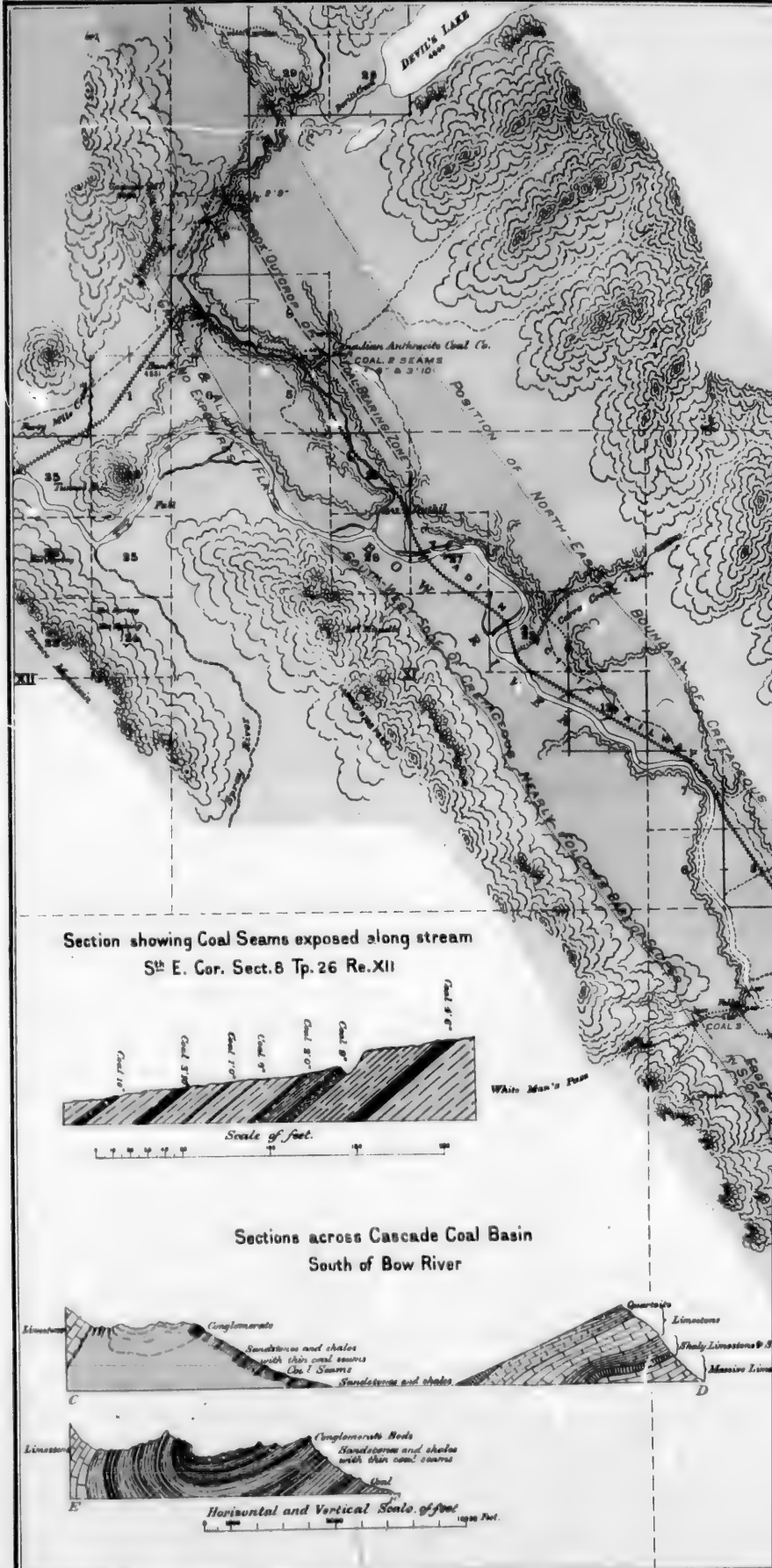
ED R. C. SELWYN C.M.G., LL.D., F.R.S., DIRECTOR.
GEOLOGICAL MAP



DRAWN BY L. N RICHARD, B AP SC

GEOLOGICAL AND NATURAL HISTORY SURVEY OF CANADA

ALFRED R. C. SELWYN C.M.G., LL.D., F.R.S., DIRECTOR.

GEOLOGICAL MAP

OF PART OF THE

CASCADE COAL BASIN

ROCKY MOUNTAINS

TO ILLUSTRATE REPORT BY

GEORGE M. DAWSON D.S., F.G.S.

1886.

Surveyed lines from Dominion Lands Branch and C.P.Ry. Surveys. Topography chiefly from sketches and Surveys by J. White C.E. with additions by R.G. McConnell B.A.

Scale of Miles

0 ¼ ½ ¾ 1 4 5

Cretaceous Coal-bearing rocks (Kootanie Group)

Carboniferous and Devonian (Limestone Series)

Magnetic North

26

25 IX

24

X

D

F

Quarry in Limestone

Shaly Limestone & Shale

Massive Limestone

PHOTO LITH BY THE BURLAND LITH CO MONTREAL

extremity on the Kananaskis it has now been continuously traced to the Red Deer River, a total distance of sixty-five miles, and it is still found running to the north-westward, parallel to the enclosing ranges of mountains beyond that river to an undetermined distance. It is probably coal-bearing in character throughout, as coal has been found in a number of places from one extreme of its known length to the other.

Outlines of coal-bearing area.

The portion of this Cretaceous trough included by the accompanying special map, is about thirty miles in length, and has a total area of over sixty square miles. The quantity of drift material present, and the wide spread of the shingle terraces, above alluded to, in this part of the valley, renders the detailed investigation of the structure of the field difficult; but the great regularity of the strike of the rocks to some extent counterbalances this, and the general structure of the trough is now fairly well understood. The south-western edge of the trough is pretty clearly defined by exposures throughout, with the exception of that portion between Cascade Mountain and Mount Rundle, but the north-eastern is for most of its length entirely concealed. The limestones on this side are known by isolated exposures to extend from a mile to two miles from the base of the mountains, into the bottom of the valley itself, and the strike of the beds indicates the position of their junction with the Cretaceous to be nearly as shown on the map, though pre-glacial denudation may have removed the thin overlapping edge of these rocks for considerable widths in some places, leaving a gravel-filled hollow of unknown width along the outcrop as indicated hypothetically in the section shown in Fig. 8.

FIG. 6. OVERTURNED ANTICLINAL OF LIMESTONE ROCKS NORTH OF ENTRANCE TO WHITE MAN'S PASS.

Its general structure.

The Cretaceous rocks may be described, in general terms, as forming a long, narrow synclinal fold, which, owing to the immense pressure from the south-westward, has been bodily overturned in the opposite direction; the mountain range on the south-west side being composed of an anticlinal of the limestone series, similarly compressed

and folded over on the Cretaceous rocks. Owing to this circumstance the direction of dip of the rocks in the mountains bordering the valley on either side, and in the intervening Cretaceous trough, is almost uniformly to the south-westward. This fact at first induced the belief that the Cretaceous rocks were bounded, along the base of the south-western mountain range, by a very extensive fault, with down-throw to the north-eastward, but further investigation proved this view to be incorrect.

Overturned anticlinal and synclinal.

Figure 6 shews the overturned anticlinal in the range to the south-west, as actually observed in the mountains to the north of the entrance to the White Man's Pass, opposite Canmore station. Figure 7 is a sketch illustrating the synclinal form of the Cretaceous rocks,

FIG. 7. SECTIONS OF CRETACEOUS SYNCLINAL SHOWN IN RIDGES BETWEEN BOW AND KANANASKIS RIVERS.

as shown in a series of high ridges which run out from the base of the Wind Mountain range. In this, the wooded slope on the right, together with the distant rough summits, which are vertically shaded, are composed of rocks of the limestone series, while the intervening ridges show five successive cross-sections of the Cretaceous synclinal, in which the character of the folding is clearly evidenced by certain more prominent beds of conglomerate and sandstone. This structure may be seen at a glance, in looking down the valley to the south-eastward from points between Canmore and Grotto Mountain, from one of which the sketch here reproduced was taken.*

Minor complications.

Though thus comparatively simple in its great structural features, this Cretaceous trough is complicated by minor irregularities, which will require to be allowed for in connection with the tracing out and working of the coal-seams; though, on account of the general paucity of exposures, it is yet difficult to do more than indicate their existence. The south-western border of the trough, though spoken of as primarily characterized by the folding back of a limestone anticlinal upon the Cretaceous rocks, is probably in many cases accompanied by more or

* It should be remarked that Dr. Hector clearly recognized the synclinal structure here met with, and shows in his section, No. 24, the same ridges here illustrated. His sketch must have been made from a point near the base of Grotto Mountain. Journals, Detailed Reports and Observations Relative to the Exploration under Captain Palliser, etc., p. 321. See also Quart. Journ. Geol. Soc., Vol. XVII., p. 442, Fig. 11.

less faulting. This is clearly shown on Mr. McConnell's section C–D (on the map), though the actual line of the fault separating the two series is there only diagramatically indicated. In this, and other cases, the character of the pressure to which the rock series has been subjected may have been such as to produce over-thrust faults, in which the older rocks have been pushed bodily over the newer, along a nearly horizontal plane. On the Cascade River, and beyond it, near the north-west corner of the map, the north-eastern border of the Cretaceous is also pretty evidently accompanied by faulting, and it is scarcely likely that the area of the Cretaceous rocks itself is altogether free from such disturbance,—a point to be borne in mind in estimates of the amount of workable coal in given areas. Faults.

There are also indications of a tendency to the production of a minor anticlinal fold in the Cretaceous rocks, near their south-western edge. Such a flexure is clearly shown between the Bow River and the base of the mountains at the entrance to the White Man's Pass, near Canmore, where the exposures are more than usually numerous, and is shown in Fig. 8. Disturbance of the character of that found to occur along the western edge of the Crow Nest Cretaceous trough on Mist Creek (see Fig. 5, page 100 B), may also be looked for in the corresponding part of this Cretaceous infold. Subsidiary anticlinal.

The total thickness of Cretaceous rocks actually known to be represented in this basin is about 5,000 feet, but it is probable that the actual thickness will eventually be found to be considerably greater. The conglomerates seen in the high ridges near Wind Mountain occur at a horizon about 3,000 feet above that which shows the most important coal-seams. Rocks of this character were not seen in the vicinity of Cascade River, and it is probable that the portion of the synclinal there remaining does not include beds so high in the series as these. Thickness of series.

The small number of available exposures, with the fact that most of the coal outcrops do not show well-marked correspondence in thickness, or in the character of the associated beds, has so far rendered it impossible to trace out the course of the coal-seams for any considerable distance along their strikes, or to present a detailed general section in which the relative positions of the various seams and their number might be shown. It is proposed here, therefore, merely to detail the more important facts observed in connection with the various known exposures of coal. Exploration by means of boring will be necessary before the structure and relations of the coal-bearing rocks of this district are fully known. Exposures disconnected.

The first discovery of coal in these rocks is stated to have been made at the point subsequently named the "Cascade Coal Mine," on the river of the same name, about two and a half miles north-east of "Cascade Coal Mine."

Banff station. The coal here occurs in a low, rocky bank on the east side of the stream, and has been experimentally opened by a small drift, run into the bank. The drift was started nearly at the water-level, and it was found that the surface of the rock sloped downward to the east, in consequence of which, the drift in a short distance ran out into the overlying gravelly deposits. The seam is here associated with thin-bedded shaly sandstones and shales, some of the latter being quite dark in colour and finely fissile. A little ironstone in nodular layers occurs both above and below the seam. The dip is S. 53° W. $< 35°$, and the coal is 2 feet 9 inches in thickness, exclusive of a few inches at the top and bottom, which is shaly in character. The coal looks bright and clean, but is considerably broken up by jointage-planes (a number of which were noted running S. 70° W.), and by slickensiding, evidencing disturbances, which have rendered it rather tender. A seam of three inches in thickness occurs several feet below the main seam, and the total thickness of beds exposed in the immediate vicinity is about one hundred feet.

Analysis. A sample of coal collected at this place, in such a way as to fairly represent the entire seam, has been analysed and carefully examined by Mr. C. Hoffmann. (See Report of Progress, 1882-84, p. 42 B.) By slow coking it was found to give:—

Hygroscopic water	0·71
Volatile combustible matter	10·58
Fixed carbon	81·14
Ash	7·57

Beds below coal North-eastward from the coal exposure, the Cascade River cuts across the general strike of the Cretaceous rocks, and affords a fairly good, though not continuous section of the beds underlying the seam. These consist of dark shales, generally rather arenaceous, interbedded with some shaly sandstones. Though somewhat irregular locally, the dip is found generally to increase, till at the point where the rocks of the limestone series forming the north-eastern edge of the basin are reached, it is at an angle of nearly 80°, with some evidence of faulting about the junction of the two series. The thickness of Cretaceous rocks here underlying the coal is probably at least 4,000 feet. A series of massive sandstone beds, seen about a quarter of a mile east of the coal outcrop, on the upper terrace, was not distinctly recognized in the river section.

Second coal-seam. South-westward from the coal outcrop the rocks are exposed in a number of places for nearly 2,000 feet along the river, but so much local disturbance occurs that it was found impossible to measure a

satisfactory section. At about 1,700 feet along the river, however, a second outcrop of coal occurs, and this, in 1884, had been partly opened up. The seam is here at least several feet in thickness, but it has been badly crushed, and the coal appears in a more or less pulverulent condition. It occupies a horizon probably about 800 feet above the first seam, and may possibly represent the return of the same bed in the reversed south-western side of the main synclinal fold. Cretaceous shaly rocks, which form the lower spurs of Cascade Mountain directly opposite these exposures, pretty evidently represent those described as underlying the first seam further up the river.

Width of basin.

Opposite the northern part of Cascade Mountain, the entire width of the Cretaceous trough becomes reduced to about a mile, a circumstance which appears to arise from the folding back of the limestone rocks of the mountain upon the Cretaceous. In the south-eastern base of the mountain, the line of junction of the two formations gradually descends till it reaches the level of the bottom of the valley near the little cascade which gives the mountain its name.

Canadian Anthracite Coal Co.'s shaft

Two and a half miles south-eastward of the "Cascade Coal Mine," on the south-east corner of Section 8, coal seams are again exposed. A shaft has been sunk here to some depth, on the thickest seam, and so far as yet known this locality is the most promising one for the actual extraction of coal.

The lowest, and most important seam, is here 4 feet 6 inches in thickness, and is capable of yielding about four feet of good, clean coal. The dip is S. 35° W. $<$ 30°, and the measures are very regular, the coal being quite solid and of excellent quality. One hundred and thirty-five feet above this seam is a second, 3 feet 10 inches thick, which also shows excellent coal, and between these two main seams are four thinner ones, 9 inches, 24 inches, 8 inches and 12 inches in thickness respectively, in ascending order. Twenty feet above the upper thick seam is still another coal bed, 10 inches thick. There are thus, altogether, seen in these exposures, seven seams in a total thickness of 155 feet of measures, and though but two of these are of workable dimensions, the occurrence of the others is of importance in showing the persistently coal-bearing character of the rocks.

Seven coal seams.

The beds including these coals are generally shales and shaly sandstones, which present no very marked characters; but beneath the lowest seam is a thickness of one hundred feet or more of rather massive grey or yellowish sandstones, and a bed of sandstone constitutes the floor of the seam.

Thin seam.

At a point nearly a mile west of the position of the shaft, a thin, crumbled seam of coal is partially exposed in a little rocky hi' ear the bank of the Cascade River, but the intervening rocks are covered, and its relation to the other coal seams is unknown.

The identity of any of the seams here described with either of these at the "Cascade Coal Mine," is also as yet a matter of conjecture, but I have ventured, on the map, to connect the coal-bearing horizon of the two places, the great general regularity of the strike apparently warranting such general correlation.

Analysis.

The coal from the shaft, on the lower thick seam, has also been examined by Mr. Hoffmann, who reports fully upon it on page 10 M, (1885). It proves to be a fuel of exceptionally high quality, and gives by fast coking, the following result:—

Hygroscopic water	1.04
Volatile combustible matter	9.15
Fixed carbon	87.18
Ash	2.63

South-west border of trough.

Along the base of Mount Rundle, and in the range running south-eastward from it, as far as the entrance to the White Man's Pass, the limestones are seen nearly down to the level of the valley, and the edge of the Cretaceous rocks probably corresponds closely with the base of the steep slopes. No exposures were found in this part of the valley. Carrot creek, though cutting across the strike at right angles, exposes no rocks of the Cretaceous series. Opposite Canmore station, however, and near the entrance to the White Man's Pass, these rocks are seen in a number of places. The section at this place is shown, somewhat diagramatically, in Fig. 8, in which the beds marked with transverse

FIG. 8. DIAGRAMATIC SECTION ACROSS THE CRETACEOUS BASIN NEAR CANMORE STATION.

lines, represent the limestone series, and the vertically shaded layer, the superficial, gravelly deposits and terraces. The actual contact of the limestones and Cretaceous rocks was not seen, but near this line, the latter are almost absolutely vertical, and here Mr. McConnell has found a seam of coal about three feet in thickness. Nearer the Bow River, on the small stream which issues from the pass, a sharp synclinal fold occurs, and shaly beds, containing a thin seam of crumbled coal, appear in addition to the sandstones, elsewhere more prominent. On the bank of the river, three quarters of a mile below the mouth of the

stream, the beds become nearly flat, and contain a seam of good coal, about one foot thick. In shaly layers, associated with this, a number of fossil plants, characteristic of the Kootanie group were collected, among which are *Asplenium distans, Anomozamites acutiloba?* and *Pinus Suskwaensis.** Fossils.

To the south-east of these exposures, the border of the Cretaceous rocks rises gradually in the slope of the mountains, and in the base of the Three Sisters, forms a considerable part of this slope. Still further on, in the same direction, the area of the Cretaceous trough which continues toward the Kananaskis, is characterized by a series of high Cretaceous ridges, the structure exhibited in which has already been referred to. These have been examined by Mr. McConnell, and afford excellent sections, as shown on the accompanying map. Near the eastern base of the first of these ridges, occur two coal-seams, reported by Mr. McConnell as about 12 and 15 feet thick respectively. This place, which is about a mile and a half from the Bow River and 500 feet above its level, is known as "Marsh's Mine." The two coals are separated by about fifty feet of shales and sandstones, and both have been opened, an adit nearly a hundred yards long having been driven in the upper seam. The coal appears to be of good quality, but has been so much shattered in the manner previously described, that it crumbles on exposure. Mr. McConnell, however, states that coal-seams at or about the same horizon can be traced at intervals for several miles toward the Kananaskis, and believes it to be probable that localities might be chosen in which the coal would be proved to be more solid. The beds above the coals and between that horizon and that of the conglomerates are more or less coal-bearing throughout and contain a number of thin seams. Erect tree-trunks were also observed in this part of the section at several levels. These stand on dark shaly beds, doubtless, representing the soil on which they grow and extend up through beds of sandstones. The two outcrops at "Marsh's Mine" belong to the north-eastern side of the synclinal fold, and the coals do not appear on the opposite or reversed side of the fold. Cretaceous ridges between Bow and Kananaskis. "Marsh's Mine."

As already stated, much exploration, by means of boring, will be necessary before the structure of the coal basin is fully known, but its occurrence on the line of the railway (which actually runs on the Cretaceous rocks for a distance of thirteen miles), taken in connection with the excellent quality of the fuels which it is capable of affording, must be considered as a circumstance of the first economic importance. As the result of the observations made up to the present time, it may be General considerations.

* See Trans. Royal Soc., Canada, Vol. III. Sect. IV.

stated that the disturbances and subsidiary folding of the beds most likely to prove troublesome in following and working the coal, occur, for the most part, on the south-western side of the trough, or in connection with the overturned side of the main synclinal fold. The north-eastern outcrops of the coal seams, therefore, apparently possess the greatest value and should receive the first attention in the development of the field. The greatest difficulty to be apprehended is, undoubtedly, that of the crushed character in which the coal is frequently found, and though such more or less pulverulent coal, is not without value as a fuel, and may be used in locomotive and other engines constructed to burn it, it is, as a salable commodity, much inferior to the solid anthracite. The crushed character of parts of the coal has doubtless resulted from movement affecting the containing rocks subsequent to that which accompanied and probably caused the change of the ordinary bituminous coals of the Kootanie group into anthracite or semi-anthracite. As stated on previous pages of this report, bituminous coals, in other parts of the mountain area, are, occasionally, found in a similar shattered condition.

The north-western continuation of the Cascade Cretaceous trough, as far as the Red Deer River, is described on a subsequent page.

Bow River Valley (continued).

Banff to Castle Mountain siding.

Beyond Banff station, near which the Bow River enters the wide Cretaceous basin just described, the Bow Valley has a west-south-west direction for seven and a half miles, to Castle Mountain siding, cutting directly across the run of the mountain ranges. To the south there are three well-marked parallel ranges, ending at the valley in Rundle Mountain, Terrace Mountain and Mount Bourgeau. On the eastern slope of Terrace Mountain, occur several hot springs, which have already become well known. On the north the constituent ridges are not so well marked, the mountains forming part of a wide belt which is still collectively designated as the Saw-back Range, though this name belongs more especially to its western constituent ridge, which ends on the river in Hole-in-the-wall Mountain, and is composed of vertical beds of limestone. In this part of the valley a couple of small lakes, and some swampy meadows again occur, recalling those which are found in the similarly situated transverse part of the valley east of Grotto Mountain, and like those, evidently formed by interruption of the drainage by material washed in from the neighbouring mountains. The rocks composing the mountains on both sides of the valley are almost entirely of the limestone series, and show continuous high south-westward dips.

From Castle Mountain siding to Bow Lake, the valley preserves a nearly direct course to the north-west. For thirteen miles this course is oblique to the general direction of the mountains, but after passing the south end of Castle Mountain, the trend of the mountain ranges changes to the same direction with the valley, which follows the axis of an important anticlinal, in which Cambrian rocks are brought to the surface, for at least twenty-six miles. The first portion of the valley is rather irregular in width, but further on it becomes a wide, definitely bordered and parallel-sided trough like other important longitudinal valleys of the mountain region. Castle Mountain to Bow Lake.

Castle Mountain is in appearance one of the most remarkable on the Bow Valley, and contrasts markedly with those forming the western border of the Saw-back Range,—from which it is separated only by Johnson Creek (called also Silver Creek). Its higher part is formed entirely of rocks of the great limestone series, which apparently in the main, form a shallow synclinal, and have low, regular dips. As first seen from the south-eastward, its extremity appears as an almost isolated index-like pinnacle, but on closer approach this is found to be merely an outlying peak of a range of rampant-like cliffs which border the Bow Valley on the east for a distance of ten miles. Deposits of purple copper ore have been found in a number of places on and near Copper Mountain, and mining locations have been staked out, but as far as I am aware no great amount of prospecting work has been accomplished on any of them. Castle Mountain. Copper.

Opposite the south end of Castle Mountain, across the Bow River, is Copper Mountain, 8,500 feet in height. This mountain is so named on account of the occurrence of similar deposits of copper ore, and these, as work was in progress toward their development, were examined with some care in 1884. Copper Mountain.

Copper Mountain is separated by the deep, narrow valley of Red Earth Creek from the higher summit to the south-east known as Pilot Mountain, in which beds of the limestone series appear nearly horizontal or forming a low anticlinal. The summit of Copper Mountain has a crescentic outline, concave toward the north-west, with a couple of short, high ridges, interpolated between the horns of the crescent. Its eastern slopes are densely wooded, and were not closely examined, but appear to consist of limestones, also lying at rather low angles of inclination. Toward the western end of the mountain, however, these beds became quite vertical, with a north-and-south strike, and its extreme western part is composed of quartzites referable to the Cambrian series, also in a vertical attitude, as shown in the eastern part of section No. 1. The most important occurrences of copper ores are in the vertical portion of the limestones series a short distance east of its

Copper ores.

junction with the quartzites, and appear in the vicinity of one of the spurs above mentioned, three and a half miles nearly due south from Silver City station, at altitudes between 7,000 and 8,000 feet.

Work carried on.

The theory in accordance with which work was being carried on at the time of my visit, was, that the ore-deposit ran north-and-south along the spur just referred to, more or less parallel to the strike of the limestone. Copper ore had been uncovered at several places along the crest of the spur within a length of half a mile, and an adit had been run in from the valley at its eastern base for a distance of over 200 feet. It would be necessary to continue the adit for several hundred feet further before it would reach the presumed line of the ore-deposit, and no ore had, so far as I could learn, been found in the progress of the drifting.

Principal exposures of ore.

The four principal points at which some work had been done on the edge of the spur, in order from north to south, presented the following appearance:—(1). Quartz seams, in shattered limestones; the seams running nearly north and south, with an eastward dip $< 40°$. Some small specimens of good ore, but no appearance of a continuous vein. (2). A mass of quartz running N. 20° E. through the limestones, nearly vertical. This includes some small rich seams of ore, and a few bunches or pockets. (3). A fairly well-defined quartzose vein, about two feet thick, running east and west, with southward dip $< 80°$. This is colored by copper carbonates, evidently produced from the decomposition of sulphides, and is said to have yielded several fine masses of ore. (4). This is a somewhat irregular vein, but, like the others, has not very well defined walls. It runs across the edge of the spur S. 80° E., with southward dip $< 80°$. Where best developed the width is about seven feet, and is made up of a foot of barren granular quartz at each side, with about five feet intervening of good ore, consisting of copper pyrites, purple ore and copper glance disseminated, generally in pretty fine granules, through a quartzose matrix. It is much decomposed, with blue and green carbonates filling crevices, and the limestone bordering it is considerably fissured, and occasionally holds a little ore. This is the most promising of the openings, and it will be observed that both this and No. 3, run directly across the ridge or spur and the strike of the limestone beds.

Summit of Copper Mountain.

The somewhat plateau-like top of Copper Mountain is deeply covered with angular rocky fragments, which are doubtless due to the prolonged action of the frost and weather. Among these are a number of masses of considerable size, of porous, yellow and blackish gossan, which have apparently come from the decomposed outcrop of a copper vein, which must run across the summit, probably in an east and west bearing. From the size of the fragments, the vein is likely more important than

those above described, and it would not require much work to ascertain this point. On analysis the gossan proved to contain neither gold nor silver. Loose fragments of rich ore have here been found also, on the southern slopes of the mountain, and one of these, consisting of nearly pure, purple ore, weighed about seventy pounds. It is evident that the copper-bearing district is here somewhat extensive, and not improbable that rich deposits may eventually be opened up. The opinion formed on the examination of this vicinity was, however, that the ore deposits are irregular, and consist rather of pockets or "gash veins" than of true persistent lodes.

Copper-bearing area.

Specimens of the ores from Copper Mountain which have been analysed by Mr. Hoffmann, though yielding high percentage of copper, contained neither gold nor silver. In the examination of the vicinity of Copper Mountain, I was accompanied by Mr. J. Heely, the original discoverer, to whom thanks are due for his assistance.

Character of ore.

From Copper Mountain it is not difficult to travel westward, in a nearly direct line, to the Twin Lakes, at the base of the main range. The information gained with regard to the rocks in this locality appears in section No. 1. The structure is that of an anticlinal, with nearly vertical beds on the east side, but showing dips at angles of about 20° to the west. This is the continuation of the anticlinal of the upper Bow Valley. To the west of, and below the limestones of the vicinity of the copper deposits, is a considerable thickness of white and grey quartzite, with some conglomerates and schists. The centre of the anticlinal is then occupied, for a width of nearly two miles, by schistose rocks, of grey, blackish and brownish colours. They are chiefly argillites, but show incipient crystallization, which gives them a glossy appearance. In some places, slaty cleavage occurs, but the rocks generally split up parallel to their bedding. Bands of quartzite are found throughout. Almost the entire eastern front of the watershed range is composed of quartzites and other rocks of this great Cambrian series, as more fully described in connection with the Vermilion Pass (p. 119 B). The total thickness of the Cambrian rocks shown in this anticlinal, must be at least 5,000 feet. Much white or rusty crystalline quartz is scattered over the district characterized by these schistose beds, and is derived from veins which traverse them in all directions. Near the Twin Lakes, fragments of galena occur, and a vein of this mineral has been discovered and located here by Mr. Heely. A specimen, in which the galena constituted only a small part, yielded about half an ounce of silver to the the ton, on analysis by Mr. Hoffmann. (Report of Progress 1882-84 (p. 6 M M.)

Rocks from Copper Mountain to Twin Lakes.

Galena.

The mountains between Copper Mountain and the watershed range,

are, in consequence of the softer nature of the schistose rocks, charactered by low, rounded summits and ridges, which, however, rise to heights exceeding 7,000 feet. The upper slopes are almost bare, Lyell's larch being the most abundant tree.

Twin Lakes

The Twin Lakes lie at the base of the scarped and nearly vertical front of the watershed range, which rises above them in stupendous cliffs, in the rifts and hollows of which, snow remains throughout the year. The lakes give rise to a small stream which reaches the Bow near Silver City

View from Copper Mountain

The summit of Copper Mountain affords a very fine and extensive view, both of the upper part of the Bow Valley, and the wild mountain country to the south. Assiniboine Peak, with its remarkable fringe of glaciers, was best seen from this point, though about twenty miles away, and the escarpment-like front of the main, or watershed range of the mountains, may be traced for a great distance. The whole upper part of the valley of Red Earth Creek, is also in view, and its remarkable width, and light slopes, contrast strongly with the more rugged appearance of other parts of the region. These characters are due to the fact that it follows the run of the belt of schistose rocks already mentioned. These rocks were seen by Mr. McConnell near the summit of Simpson's Pass where the Cambrian area appears to terminate.

Bow Range.

The mountains on the south-west side of the Bow Valley, from Silver City onward, are very bold and high, and include Mount Lefroy, the most lofty yet actually measured in this region, with an altitude of 11,658 feet. The plate facing this page, illustrates the appearance of this range as seen from a high spur of Mount Hector, on the opposite side of the valley. The conical, snow-covered peak on the right is Mount Lefroy, while that near the centre of the view has been named Mount Temple. The greater part of the mass of these mountains is composed of quartzites and slaty or schistose rocks, with uniform, low, south-westward dips. Massive limestones appear near the summits of many of them. The Slate Mountains on the opposite side of the valley have, generally, rounded forms quite different from those of the Bow Range and Castle Mountain. Several small streams enter the Bow from the mountains on the south-west, but the greater part of the water from this range flows off in the opposite direction. On the north-east side, Baker Creek is an important stream, and Pipe-stone Creek may be called a river.* Its name is given on account of the occurrence on it of fragments of soft, fine-grained, grey-blue argillite, which the Indians have used in the manufacture of pipes. Some

Pipe-stone Creek.

* *Pa-hooh-to-ki'-agoo-pi'-wap-ta* in Stoney, *Moni'-spaw-gun-na-nis-si'-pi'* of the Crees, signifying "Blue Pipe-stone River."

parts of this portion of the Bow Valley are broken by low, rocky hills, composed of slaty Cambrian rocks.

Bow Lakes. Northward from Laggan station, to the first of the two lakes in which the Bow rises, the valley preserves similar structural characters, but is more densely and uniformly wooded than before, and often very swampy. The first of the Bow Lakes (where our examination ended in this direction), is a fine sheet of water, four miles in length, and at an elevation of 5,530 feet above sea-level. Its lower end extends into the valley, and is separated from the river only by a narrow tract of flat land, composed of gravelly and other detrital material. The greater part of the lake, however, lies in a deep valley between the northern end of the Waputtehk Mountains and Sheep Mountain, both of which rise from it almost perpendicularly. On the mountains at its upper end is a considerable glacier, fed by a large snow-field of unknown extent to the westward.*

Kicking Horse Pass. The railway, beyond Laggan, follows Noore's Creek for three miles, after which it ascends by the valley of a small tributary stream to the actual summit of the Kicking Horse Pass, at an elevation of 5,296 feet (on the railway grade) above the sea. The transverse valley forming the Kicking Horse Pass, where it traverses the watershed range, repeats in its main features those of the Vermilion Pass, previously noticed. It is not necessary here to enter into any general discussion as to the origin of such transverse valleys, but it may be stated that the present conditions fail to explain the origin of this comparatively wide trough, which has been excavated at right angles to the watershed range. It appears highly probable that the stream now flowing to the Bow may originally have had its sources much further west than the present summit, and that the head-waters of the Kicking Horse, in consequence of the greater fall on that side, have cut back eastward, reducing the area which drains to the east. Bedded gravel deposits occur about the actual summit, in positions which imply the presence of a considerable body of water at levels higher than are possible under the actual circumstances. Rock surfaces near the same place were observed to show glacial striation in an eastward direction.

Rocks. Geologically, the mountains about the summit have, in the main, a synclinal structure, rocks referred to the great limestone series coming down to the level of the bottom of the valley for about two miles near the height of land. Below these, a short distance west of the Kicking Horse Lake, a few fossils were discovered in 1884, in exposures newly made along the railway line, by members of the visiting party of the British Association for the Advancement of Science.† Among

* The Bow Lakes are called *Mi'-nie-ne-im-ne* in Stoney, *Os-kow-wioo-si'-pi'-sa-ga-he'-gun* in Cree meaning Coldwater Lakes.

† See p. 14 B.

Cambrian fossils.

specimens obtained at that time, Mr. C. D. Walcott has recognized *Olenellus Howelli* and *Olenoides lævis*, trilobites characteristic of the Prospect Mountain Group of Nevada or Middle Cambrian.

General geological features.

The geological structure of the mountains near the Kicking Horse River, is, if anything, more intricate than that of most parts of the mountains, and as it is now being investigated in detail by Mr. McConnell, any description which I might give of it from my own reconnoissance work would probably be greatly modified by the result of his examinations, which will shortly be published. On the map, an attempt is made to separate the quartzite and slate series, from the overlying great limestone series which is referred to the Devonian, or Devonian and Carboniferous. It should be noted, however, that the existence of passage beds between these and the quartzite series was suspected in this place, and that Mr. McConnell informs me that he is of opinion that Cambro-Silurian and Silurian rocks also probably occur here. It may be stated also, that the slaty and schistose rocks seen near the Otter-tail, closely resemble those found on the continuation of the same strike in the Vermilion Valley, while those near the mouth of the Beaver-foot are quite analogous to rocks seen further

Ore deposits.

to the south-eastward in the Beaverfoot-Kootanie Valley. Since the date of my examinations, also, a number of metalliferous deposits have been discovered, and some of these have been opened and prospected to a considerable extent. Most of these are in the vicinity of the mouth of the Otter-tail, and near Mount Stephen. The ores so far examined in the laboratory of the Survey consist largely of galena, which is generally associated with more or less copper pyrites. They contain, however, but a low percentage of silver, and gold is practically absent. Some of the lodes are reported as wide and continuous. Assays of a number of specimens will be found in Mr. Hoffmann's reports. (Report of Progress, 1882-84., Report M M. Annual Report, 1885., Rep[illegible] M.)

Kicking Horse Valley.

The descent of the branch of the Kicking Horse which rises in the pass, is at first very rapid, but on reaching the bottom of the valley, this branch is joined by a larger stream, at the head of the valley of which a fine glacier appears. For several miles almost the entire width of the valley is occupied by gravelly bars, evidencing the great volume of water which at some seasons must descend from the mountains. On the south side of the valley are Cathedral Mountain and Mount Stephen, picturesque spurs from the northern end of the Bow Range. Further down, the valley of the North Branch, which is remarkably wide, opens northward, and several glaciers and snow-fields appear on the mountains, which a few miles further up rise to heights of 9,000 to 10,000 feet. The river makes an acute angle round the south end of

of Mount Hunter, and forms a fall of about forty feet in height near the apex of this angle. Down to Palliser station, the valley continues moderately wide, but below that point becomes gradually more constricted, and before reaching the Columbia Valley, flows for some miles in a deep cañon, falling from ledge to ledge as a wild torrent.

Devil's Lake and Vicinity.

Devil's Lake.* ten miles long and about half a mile in width, occupies part of a very remarkable, transverse valley, which runs across the outer ranges of the mountains to the east, separating the Palliser Range from the Fairholme Mountains. It has already been stated, that this valley presents all the appearance of having at some former time been that of a large river, and it is probable that at a period antecedent to that of the glaciation of the mountains, the Bow River flowed through it. The valley is parallel-sided, and bounded to the north and south by high and abrupt mountains. Its western part is now occupied, for its whole width, by the lake, while to the east, its nearly level floor is formed by drift deposits, and two small lakes have been formed by the damming of the valley by the delta deposits of lateral torrents. The Devil's Lake has an approximate elevation of 4,800 feet, and discharges by a rather small, tortuous and somewhat sluggish stream, into the Cascade River, above Banff. The water of the lake is clear, and it is evidently deep, though very often showing a shallow border, which, at a few hundred yards from the shore, ends suddenly with a terrace-like front. This is a feature not uncommonly found elsewhere, but it is here apparent, through the clear water of the lake, that this shallower border is generally formed of gravel deposits, which have been cemented by calcareous matter into a species of conglomerate, which is broken into irregular blocks, about the outer or escarpment-like edge.

Devil's Lake.

Shallow border of lake.

The forms of the mountains about the lake are particularly varied and bold, and Peechee's Mountain, to the south, rises to a height of about 10,000 feet. Fans, or delta deposits from lateral valleys project short distances into the lake, and it is finally terminated to the east by one of these of dimensions larger than usual. Beyond this, the valley appears to rise gradually eastward, obtaining its greatest height at its eastern opening to the foot-hill country, where it is stopped by irregular terraces and ridges, some of the latter being, very probably, of the nature of moraines. A short distance farther east, the Ghost River is met with. Its valley is here excavated in deep, gravelly deposits, which,

Devil's Gap.

*Called *M'ne'-sto*, or "Cannibal's Lake," in Stoney, *Ki'-noo-ki'-mote*, or "Long Lake," in Cree.

in some places, form low cliffs, having become cemented by a calcareous deposit. It would appear that the covering of detrital deposits is very deep, both in the Devil's Gap, and on this part of the Ghost River. The river, when not in flood, entirely disappears here, leaving a wide, dry gravel-bed for some miles. The smaller lakes in the Devil's Gap have no visible outlets, and are evidently subject to considerable increase in spring, when surface water is, doubtless, supplied more rapidly than the drainage through the gravel beds can remove it. No rock in place is seen in any part of the flat valley of the Devil's Gap, which is bordered on both sides by towering cliffs, in some places perfectly vertical to a height of 1,000 feet or more. Figure 9, gives an idea of the general appearance of this singular valley, as seen in looking in an eastward direction out towards the foot-hills from the west end of the larger little lake.

FIG. 9. DEVIL'S GAP VALLEY, LOOKING EAST.

Rocks.

The rocks seen near the valley are almost entirely limestone, which, though with minor flexures, appears to dip generally south-westward, along the lower two-thirds of the lake. The rocks then form a low anticlinal, next a low synclinal, and at the eastern base of the range are found with the usual south-westward dip. The character of the junction of the limestones with the Cretaceous rocks of the foot-hills, is here unknown. The angles of inclination of the beds throughout the valley are, so far as observed, uniformly rather low.

Fossils from Cascade Mountain.

On the slopes of Cascade Mountain, in fragments derived from the higher cliffs, a number of fossils have been found, but these, for the most part, are poorly preserved. They indicate, however, a Devonian or Carboniferous age, and include, besides numerous fragments of

crinoids, two species of *Productus*, *Athyris Royssii* (?) *Atrypa reticularis*, *Orthis*, sp. (a resupinate form), *Spirifera*, two species, *Straparollus Nevadensis* (?) and a *Cypricardinia*.

Fossils from Cascade River.

The beds immediately underlying the Cretaceous rocks on the north-east side, near the mouth of Devil's Creek, are calcareous sandstones, passing, in some places, into quartzites, and weathering to reddish or yellowish tints. These resemble those elsewhere seen in the upper part part of the limestone series (See pp. 73 B., 74 B., 113 B., etc.) and are probably of Carboniferous age. Their thickness at this place is several hundred feet, and they form a series of low, rough, rocky ridges, which run obliquely across the Cascade Valley. Moderately well preserved specimens of *Productus semireticulatus*, of a *Rhynchonella*, (apparently closely related to *R. mesacostalis*) and an *Aviculopecten*, (probably a new species), were obtained from them.

Cambrian.

In rocks derived from the mountains about the gorge which opens on the valley from the north, a mile and a half east of the upper end of Devil's Lake, a specimen of *Ptychoparia Oweni*, M. & H., indicating a Cambrian horizon, was found, but no outcrops of the Cambrian quartzites or slaty rocks were observed. At the same place, it was noted that in the wash from the gorge, pieces of soft shales occur, resembling those of the Cretaceous.

Upper Valley of Cascade River and Route thence to the Red Deer.

The route here described follows the northern continuation of the Cascade Cretaceous trough, and was traversed for the purpose of ascertaining its length and character. (See p. 134 B.)

Cascade River.

The stream now called the Cascade River, is roughly indicated, but not named, on Palliser's map. It is designated *Pa-ma-sae-wap-ta* in Stoney, *Ka-kīs-kī-kwe-niht-sī-pī* in Cree, both names referring to a story of a murder, in which an Indian is said to have cut off the head of a companion.

Upper part of Cascade Valley.

For three miles above the mouth of Devil's Creek, the river flows in a rocky gorge, between limestone ridges, close in to the mountains which form the north-east side of the valley. The eastern edge of the Cretaceous rocks runs nearly up the centre of the valley, directly across the bend of the river. A straight, narrow, subsidiary valley marks the junction of these rocks and the limestones. Both series at first dip westward at high angles, but further north the Cretaceous rocks dip at a low angle to the east, and their junction with the limestone series is evidently a faulted one. Nine miles above the mouth of Devil's Creek, a stream from the mountains to the eastward, supplies

about half the volume of the Cascade River, and following the valley five and a half miles further, Saw-back Creek joins from the range of the same name on the west. A low, steep-sided ridge here occupies the centre of the valley. This, seen from the south-eastward, appears conical in form, and the course of the valley is so direct that it may be observed from the vicinity of Canmore, twenty-five miles distant in that direction. The valley, in this part of its length, averages about a mile in width, and is, for the most part, pretty densely wooded up to the mouth of the eastern tributary stream above mentioned. Thence to Saw-back Creek there are a number of little open meadows. The mountains to the west are connected with Cascade Mountain, and form a continuous range from 8,500 to 9,000 feet in height, though decreasing gradually northward, and terminating near the mouth of Saw-back Creek, where the next range to the westward becomes that which borders the valley. In the north part of Cascade Mountain, the Cretaceous rocks form the lower third of its total height above the valley. In the mountains further on they rise gradually till they occupy about half the height of the mountain sides. The line of junction then descends again in the slopes, till it reaches the level of the valley. The limestone rocks, forming the higher parts of the range, are in several places clearly seen to preserve the anticlinal character found in the Mount Rundle range, further to the south-eastward; but the anticlinal has not been so completely overturned on the Cretaceous trough, and it runs out in a point, in the northern part of the ridge near the mouth of Saw-back Creek. Rocks which appear to be Cretaceous, are seen on the western side of this mountain range, some miles southward from this point, and it is probable that a subsidiary infold of the Cretaceous occurs behind the first range, as indicated on the map, though its dimensions are shown only conjecturally.

Saw-back Mountains.

Mountains east of valley.

The mountains on the opposite side of the valley are broken in their southern part by a number of deep transverse gorges. South of the large eastern tributary, previously mentioned, a narrow band of the Cretaceous rocks is seen high up on their slopes. This evidently represents the eastern edge of the main Cretaceous synclinal let down by a fault parallel to its direction. The same band is probably continued for a couple of miles north of the tributary valley, as represented on the map, where the eastern bounding mountain ridge becomes regular and unbroken, forming a steep, nearly bare range, in which the limestone strata increase in angle of dip till they eventually become almost vertical. The whole width of the Cretaceous trough is less than a mile, a short distance south of Saw-back Creek.

North of the confluence of Saw-back Creek, the Cascade is a small, rapid stream, and both its immediate valley and the slopes of the

adjacent hills are rough and wooded, for two or three miles. Beyond this, in consequence of the increasing altitude, they become open, and the stream is found to be formed by three brooks, flowing from valleys in the Cretaceous hills. The trail follows the eastern valley, and the summit is reached at a distance of five and a half miles from Saw-back Creek, at an altitude of 6,549 feet. A well-marked trough, like an old stream-valley, runs across the summit. It is blocked here and there by newer delta deposits from lateral tributaries, one of which has produced a small pool, in which rises a little stream, flowing in the opposite direction. This stream, falling about 500 feet in four miles, reaches the deep, transverse valley of the Panther River,* a tributary of the Red Deer, which flows eastward through the limestone range to the right.

Source of Cascade River.

Panther River.

The same transverse valley is continued to the westward into the eastern front of the Saw-back Range, but its upper part is wide, and bordered by the rounded and wooded Cretaceous foot-hills of the Saw-back Range. Still continuing in the same general northward direction, a branch of the Panther River is followed up to a second summit, five miles beyond it, with a height of 7,263 feet. The valley of this stream is at first a deep narrow ravine, which the trail follows on the east side. Near the summit, however, it becomes wide and moor-like, with low thickets of willow and birch, and rough tussocky grass. Beyond the summit, a stream, which rises in the hills to the east, enters the valley, and turning at right angles, joins the main Red Deer River in five miles further. Its valley is generally wooded, and the stream flows in a deep, narrow gorge. The height of the Red Deer at the mouth of this stream is, approximately, 5,500 feet.

Panther River to Red Deer River.

A short distance north of Saw-back Creek, the Cretaceous trough attains a width of about three and a half miles, and about the sources of the Cascade, is a region of Cretaceous hills, which, though rounded in outline as compared with the rougher aspect of the limestone mountains, reaches heights of about 1,000 feet above the summit level. The plane of the present surface of the country is evidently near that of the top of the limestone series and base of the Cretaceous, and, in consequence of this, the flexures of the strata render the outlines of the formations complicated and irregular. Opposite the summit, on the east, the Cretaceous appears to fold completely over the limestone ridge, which has up to this point been continuous, as shown on the map. Further on, the denuded crest of this anticlinal again exhibits the limestone rocks, which resume as a continuous ridge, in the Bare

Complicated outlines of formations.

* Panther River is probably a sufficiently near approach to the Indian name of the stream, which signifies "The river where the mountain lion was killed." This, in Stoney, is rendered *It-mos-tunga'-moos-ta-ga-te'-wap-ta'*; in Cree, *Mis'-si'-pi'-sioo-ka'-nipa'-hiht-si'-pi'*.

Mountains. The western side of the Bare Mountains is, however, formed altogether of Cretaceous sandstones, which dip westward at an angle of about 60°. The relations of the Cretaceous and limestone series, in this range where cut across by the Panther River, as they appear in the mountain on the north side of the valley, are illus-

FIG. 10. NATURE OF JUNCTION OF CRETACEOUS AND LIMESTONE SERIES IN BARE MOUNTAINS.

trated in the section to the left on Fig. 10. The section to the right of the same figure, illustrates, diagramatically, the flexures shown in White's Mountain, forming the north end of the Bare Mountains on the Red Deer. In both sections, the transversely marked beds represent the rocks of the limestone series.

Character of Cretaceous trough.

From Saw-back Creek to the Red Deer, the Cretaceous rocks preserve their general character as a synclinal, with overturned western edge. They dip beneath the eastern border of the Saw-back Range at angles of 30° to 40°. Much higher dips are, however, often met with in the central part of the synclinal, where the beds are sometimes vertical, and evidently much disturbed and broken. The Cretaceous rocks on the eastern edge of the synclinal usually dip westward at angles of about 60°. The various streams, along which the trail runs, have excavated the greater part of their valleys, in a belt of dark, soft, shaly rocks, which appear to be continuous throughout. East of the Bare Mountains is a second, smaller Cretaceous infold, and the explorations of Mr. McConnell, in 1885, have shown that there are additional considerable areas of Cretaceous rocks, still further eastward between these and the last limestone range which separates the mountain district from that of the foot-hills. Beyond the Red Deer, the Cretaceous rocks of the Cascade basin still continue as a wide belt running to the north-westward. We did not, however, follow them further in this direction, but turning westward by the valley of the Red Deer, travelled to the Pipe-stone and upper valley of the Bow.

Coal-seam on Red Deer.

In the northern face of Prow Mountain—a bare, bold, limestone peak—the overturned character of the western edge of the Cretaceous trough is clearly seen. On the Red Deer River, at its base, and quite close to the overlapping edge of the limestones, is an exposure showing a coal-seam several feet in thickness, but so much crumbled and broken that the precise width could not be ascertained. Coal was also observed

in the bed of a stream joining the river from the north. A specimen from the bed on the river, was found to yield a firm coke, and to be, so far as composition goes, an excellent fuel, giving 2·9 per cent. of hygroscopic water, 62·95 per cent. of fixed carbon and only 4·89 per cent of ash (see p. 7 M).

Red Deer Valley.

The Red Deer River, where first reached, is a small stream, about a hundred and fifty feet wide by six inches or a foot deep. Just above the coal outcrop, it forms a fall about thirty feet high over limestone rocks. Above this place, the valley turns to the south, and becomes very wide, a character which it preserves for about seven miles, or to the base of Mount Douglas. The lower, or northern part of the wide portion of the valley is generally wooded, and but small areas of the forest have been burnt. The timber is, however, of inferior quality. Near Mount Douglas the valley becomes open, and is characterized by gravelly hills. Several streams join the river in this part of its course, one of which, coming from the valley at the east base of Mount Douglas, is reported to rise in a lake.

Glaciers.

The south-eastern slopes of the mountain are entirely covered by an extensive snow-field, which gives rise to a glacier which fills the head of the valley just mentioned. The head of the valley, which lies between Mounts Drummond and Macoun, is similarly blocked by a wide snow-field and glacier, and one part of the summit of Mount Macoun is crowned by a cliff of blue glacier-ice, fragments of which, from time to time, fall over the vertical face of the mountain into the valley beneath. The mountains in this vicinity attain heights of 8,000 to over 9,000 feet, and are singularly varied and striking in form.

Head-waters of Red Deer.

The source of the Red Deer, at the summit of the pass between it and the Pipe-stone, is found in a small lake, at an elevation of 6,660 feet above the sea-level. From this summit a rapid descent is made to the valley of the Little Pipe-stone, the sources of this stream being at a distance of seven miles, in the mountains to the south. The valley of the Little Pipe-stone is rather wide for a stream of such small dimensions, and is, for the most part, thickly wooded. It joins the Pipe-stone at a height of 5,860 feet.

Character of rocks.

The rocks actually observed on the upper part of the Red Deer, and along the Little Pipe-stone, are almost altogether limestones, and the whole of this part of the mountains is coloured on the map as belonging to the great limestone series. It is, however, more than probable that areas of the underlying series of quartzites and slaty rocks come to the surface in some places, as the region is much disturbed, and the dips often high. In the mountains between Prow Mountain and Mount Douglas, the strata become quite vertical. The beds in Mounts Drummond and Douglas, dip south-westward at angles of about 20°, those in Mount Macoun, in the same direction, but at a lower angle. The range

on the east side of the Pipe-stone Valley, shows dips in the opposite direction, indicating a general synclinal structure. Cambrian quartzites and slaty rocks occupy the valley of the Pipe-stone, in the form of an anticlinal, the axis of which rises southward, causing the limestones to recede from the valley as it approaches the Bow. The higher parts

Mount Hector.

of Mount Molar (of Hector) and of the Mountain to the south of it, in the same range, to which I have given the name of Mount Hector, are composed of rocks of the limestone series, but the high, long spur, which runs southward from Mount Hector, is formed altogether of greenish, reddish, or purplish, slaty or shaly argillites, and quartzose conglomerates of the Cambrian series. The range, which includes Mounts Molar and Hector, has a synclinal structure, and is flanked by the Cambrian anticlinals of the Pipe-stone and Bow valleys, on the east and west sides respectively.

View from Mount Hector.

The plate illustrating the Bow Range, facing page 138 B, is from a photograph taken from a point on the long southward spur of Mount Hector, just alluded to, above the timber line, at an elevation of about 7,000 feet, when these higher parts of the mountains were covered with freshly fallen snow. The plate, however, includes only a portion of the magnificent panorama of the central and higher part of the Rocky Mountains which this point affords. It commands the entire length of the Bow Valley, from the upper lakes to Copper Mountain, and will well repay any one who may be sufficiently enterprising to reach it. A trail suitable for horses, could be made from Laggan station to this place at a moderate expense.

The Columbia-Kootanie Valley.

Tobacco Plains.

To complete the general description of the routes travelled within the portion of the mountains included by the present report, it now only remains to add a few notes respecting the great valley of the Columbia and Kootanie rivers. It has already been noticed at some length in connection with the preliminary chapter on orographic features (p. 28 B), which may be referred to in this connection.

The part of the Kootanie Valley near the forty-ninth parallel has long been known as the Tobacco Plains. It is entitled to be named plain only in comparison with the neighbouring mountainous regions, and the continuously open country extends but a few miles north of the international boundary. The bottom of the wide valley is here composed of gravelly hills which appear to represent moraine ridges in a more or less degraded state. These become lower on approaching the river, and are surrounded by wide, gravelly terraces, which in sections on

the Tobacco and Kootanie are seen to consist of white silt, with interbedded coarse gravelly layers, and are probably due to the closing epoch of the glacial period, when the valley was filled by an extensive body of water, into which turbid glacier streams from the neighboring mountains discharged. As already mentioned, the total annual rain-fall must here be very small, and it is in consequence of this fact that the 'plains' have remained without a forest covering. They are characterized by scattered groves of the yellow pine, with larch and Douglas fir. The soil is in general rather light, and sandy or gravelly in character, but where the silty deposit forms the surface, it is capable of producing fine crops when irrigated. Numerous steep-sided hollows, without outlets, some of which hold pools and small lakes, occur among the moraine hills, and here and there pit the surfaces of the terraces. Large ice-carried blocks of the rocks of the mountains are in some localities pretty thickly scattered, but rock in place seldom appears in the valley.

Valley northward to Elk River.

Northward to the Elk River, the same conditions prevail, but the country becomes more generally wooded, the open tracts being almost restricted to the terraces along the Kootanie. The Elk is crossed near its mouth by a ford, which, except at low water, is deep, and dangerous owing to the rapidity of the current.

Country north of Elk River.

From the Elk to Wild Horse Creek, the wide belt of low country lying between the Kootanie and the western range of the Rocky Mountains continues to maintain the general character of that further south. Between the Elk and lower part of the Kit-a-mun River and Sand Creek is an extensive tract, with scattered groves of yellow pine, and the other trees previously mentioned, having a park-like appearance, and capable of affording abundant pasturage. Here some of the moraine ridges were observed to have a more or less distinct semicircular form, open to the northward. The soil is usually light, but the flats near the river and some of the lower terraces, which are of considerable width, would be suitable for cultivation if irrigated. On approaching the base of the mountains the surface becomes generally wooded, and for some miles south of Wild Horse Creek it is rough and very evidently composed of slightly modified moraines.

Bull River.

Bull River, like the Elk, is difficult to cross at high water, and a narrow bridge has been thrown over it at the point at which it leaves the mountains, where it appears as a wild torrent, flowing for half a mile or more, in a deep and very narrow cañon. As a considerable detour is necessary in order to reach this bridge, it is used only when the river is at a high stage. North of the bridge is a high mountain, visible from a long distance to the southward, and identified as "The Steeples" of Captain Blackiston.

Joseph's Prairie

Near the mouth of Wild Horse Creek, a ferry has been established across the Kootanie, and nine miles south-westward from it is Joseph's Prairie, where, for many years, Mr. Galbraith has, with the help of irrigation, raised excellent crops. The country between the Kootanie and Joseph's Prairie is undulating or hilly, partly wooded, and with occasional small projections of slaty Cambrian rocks. It forms an excellent cattle range, and in this connection it may be stated that the entire valley, from the forty-ninth parallel to beyond the Lower Columbia Lake, affords much excellent bunch-grass pasturage, and is well adapted for the support of a considerable number of cattle and horses.

Cattle country.

Outlines of formations.

Owing to forest fires in the neighboring mountains, and the consequent dense and persistent smoke, little was seen of the mountains forming the eastern border of this great valley, between the forty-ninth parallel and Wild Horse Creek, and the outline of the western edge of the limestone series is shown on the map with approximate accuracy only. The greater part of the valley is, however, without doubt, underlain by Cambrian slates and quartzites of the usual character, and Mr. Bauerman's previous observations show that these rocks also characterize, for a long distance, the mountains to the west of the valley near the forty-ninth parallel.*

Rocks near Elk River.

These rocks appear to lie in a series of wide undulations, generally at rather low angles. Near the mouth of the Elk, some exposures occur of greenish and grey fine-grained quartzites, precisely resembling those previously described as the Elk River bridge beds (p. 78 B). At this place, some purplish beds also appear, in which small pseudomorphous impressions of salt crystals (see p. 55 B) were observed, together with ripple-marked surfaces. Rocks of the same general character are seen in a few places north of the Elk River, but as no connected section can be offered, it is considered unnecessary here to describe them in detail.

Limestone area

On the lower part of the Bull River, near the banks of the Kootanie to the south of it, and elsewhere in this vicinity, rocks of the limestone series occur. The area affording these exposures, is outlined in a general way on the map, and is supposed to be bounded to the east by an extensive fault, which must run near the base of the mountains. The limestone is grey in colour, lies generally at rather low angles, (not exceeding 20° so far as observed), and resembles that forming the upper portion of the Devono-Carboniferous on Crow Nest Lake, in the abundance of crinoidal fragments, though no other fossils were seen in it. North of the Bull River, near the trail which leads to the bridge,

* See Report of Progress, 1882-84, p. 25 B.

and not far from the base of the mountains, a low, isolated hill was found to be composed of a remarkable crystalline rock, which is evidently intrusive. It is chiefly composed of well-formed, orthoclase felspar crystals, which are pinkish in colour, and, in some cases, nearly an inch in length. The rock is rather porous, owing to the decomposition which it has suffered, and its jointage-planes are coated with rusty incrustations and micaceous hæmatite. It may be regarded as a variety of quartz porphyry in which the quartz is, however, observable under the microscope only. As loose pieces of a similar material were found in Elk River, it is possible that other similar intrusions occur elsewhere in this neighborhood. Quartz-porphyry.

Near the base of The Steeples, and at the bridge over Bull River, are numerous exposures of quartzites, of greenish and brownish colours, passing into grey tints and interbedded with, and merging into blackish argillites and slaty rocks. Some layers become conglomeritic, the pebbles being composed of a black, somewhat silky schist. The dips are in general eastward, at rather high angles, though locally disturbed. The rocks being on the strike of those on the Hughes Range, may be taken as typical of those composing it. A number of strongly marked jointage-planes, which run parallel to the direction of the base of the range, with high dips to the westward, may be connected with the supposed great fault previously mentioned. Small quartz veins are numerous, and become rusty and porous on weathering, from the removal of dolomitic matter. They were observed to include also little segregations of iron and copper pyrites. Gold has been obtained in paying quantity on Bull River, near this place, but only at very low stages of the water. Near the mouth of the river, we obtained numerous 'colours' by washing the gravel of the banks. A few 'colours' to the pan were also found on Sand Creek. On Bull River, near the bridge, loose boulders occur, of a fine-grained, granular hæmatite, seamed throughout with green and blue carbonates of copper. On assay it proved, however, to contain neither gold nor silver (see p. 26 M). Rocks on Bull River. Veins. Gold.

The drift material observed in the Kootanie Valley, south of Wild Horse Creek, is chiefly of the ordinary Cambrian rocks, or of limestone. Besides these, however, pebbles of whitish, granitoid rocks were occasionally seen. Such rocks do not occur in the Rocky Mountains, and it is probable that these pebbles have been derived from the Purcell or Selkirk ranges, on the west. Pieces of lignite were seen in the gravel of Sand Creek, and a large fragment of foliated lignite was picked up on Bull River. The occurrence of this material appears to afford proof that Tertiary rocks, resembling those of the Flat-head, occur also in the wide valley of the Kootanie in this vicinity. The quantity of superficial material, however, renders it impossible to define this area, even approximately. Drift in Kootanie Valley. Probable Tertiary area.

Wild Horse Creek.

Wild Horse Creek, named Skirmish River on Palliser's map, has been, from the first, the gold-mining centre of the Kootanie district. Its auriferous character was discovered in 1864, and it was this discovery which first drew the attention of miners to the Kootanie country. Since 1864, placer mining has been continuously carried on,

Placer gold mines.

and the total value of the gold obtained is probably not much less than $500,000. From 1878 to 1885 the returns show a yield of $188,380. Where it reaches the Kootanie, Wild Horse Creek is, at low-water, a swift stream of about forty feet in width by one in depth. For about two miles from its mouth, it occupies a deep trough, which it has excavated in the silty and gravelly terrace-deposits of the main valley, and this part of its course is now much obstructed by tailings washed down from the mines above. Further up, the valley is narrower, with steep banks, which show many exposures of rock, and high and very steep mountains rise above it on both sides.

Character of the mines.

The portion of the valley in which successful mining operations have been carried on, is about two miles only in length, and extends north-eastward into the Hughes Range, from the base of the mountain slopes. The 'bed rock' was reached at no great depth below the bed of the present stream, in this part of its course, and was found to yield much coarse gold; nuggets valued at $100, being frequently obtained. Endeavours to reach the channel of the old river further down, have so far been unsuccessful. A sum of $10,000 was expended in one such attempt, but the surface of the rock, when reached, was found to slope steeply down beneath the detrital deposits of the great Kootanie depression, and work was abandoned. The mining has, consequently, now, for some years, been confined to the "side-ground," consisting of narrow, terrace-flats, which border the stream, and irregular sheets of gravel and detrital matter which lie upon the slopes. Of late years, the mining has fallen almost altogether into the hands of the Chinese. There is still much of this 'side-hill ground,' and, though portions of it are probably too poor to be worked in the manner employed hitherto, it is probable that the whole might be utilized with advantage with the aid of suitable hydraulic appliances.

The gold obtained is valued at $18·25 per ounce. No platinum, silver or galena have been found with the gold in the sluice boxes, magnetic iron sand being its usual associate.

Origin of the gold.

The gold of Wild Horse Creek is evidently of local origin, but no gold-bearing quartz has yet been observed in its valley. The rocks in the Hughes Range, to the south of Wild Horse Creek, dip north-eastward, at angles averaging about 40°, and the range presents a steep escarpment-like front to the Kootanie. They consist, so far as observed, of quartzites, blackish and greenish schistose-

rocks and argillites, with some compact greenstones, which probably occur as interbedded masses. Rocks of the same character are represented on Wild Horse Creek, but the strike there changes to a nearly north-and-south bearing, and the beds are nearly vertical. In ascending the valley, the first rocks met with, at the base of the range, are greenish-grey, rough and rather massive schists. Following these, are blackish, greenish and grey, rather silvery schistose rocks, not distinctly micaceous, but probably owing their lustrous appearance to talc or chlorite. They are sometimes essentially argillities, but very often, on cross-fracture, prove to be fine quartzites. Cleavage is in some places distinctly marked, but its strike is parallel to that of the bedding. These blackish and silvery schistose rocks run with the valley in its auriferous portion, and are probably the source of the gold. They are traversed by very numerous seams and veins of quartz, and bands of the schist have become in places more or less completely silicified throughout; the whole evidencing much segregative and probably hydrothermal action. No large or regular quartz veins were, however, observed. The small veins generally contain spathic iron and dolomite, as well as quartz, and were noticed also to hold iron- and copper-pyrites, and minute specks of galena. They resemble much those seen near Bull River bridge (p. 151 B). The gold now found concentrated in the bottom of the valley has apparently been derived from the wearing down of a great mass of these schistose rocks with their contained quartz veins, none of which may be individually of such size as to pay for working. It is by no means improbable, however, that persistent veins of workable dimensions will be found in this rich little district, and now that the placer deposits have so much deteriorated in value, attention should be turned in that direction.

Rocks on Wild Horse Creek.

Veins.

From Wild Horse Creek northward to the point at which the Kootanie enters this wide valley, no features occur requiring lengthened notice. The wide trough in which the river flows shows flats, some of which are cultivable, and others, which are evidently flooded at times of high water, would afford much good hay. This axial trough is bordered by low terraces, which are often of considerable width, and produce good grass. The valley is more generally wooded than in its southern portion, but is seldom thickly forested till the bases of the mountains are approached. The Lussier River, a stream about equal in size to Wild Horse Creek, is the only considerable tributary from the east, rendering it evident that the Bull River must unwater the greater part of the country behind the Hughes Range. This range, north of Wild Horse Creek, is less regular in form, and shows more prominent peaks than to the south, but appears through-

Kootanie Valley north of Wild Horse.

out to be composed of similar rocks. North of Lussier River, the limestones again form the range bordering the valley. Partial views obtained (when the smoky character of the atmosphere happened to be abated by showers) of the mountains on the west side of the valley, showed these to be rounded in form, and not very high, and it is probable that the greater part of the Purcell Range is formed of similar Cambrian rocks. The peculiar relations of the Kootanie to the Upper Columbia Lake have already been noticed (p. 29 B). The white, silty deposits continue to form the basis of most of the terraces along the valley, and were seen near the head of the Upper Columbia Lake, at a height of about 300 feet above it, or 3,000 feet above sea-level.

Upper Columbia Lake.

The Upper Columbia Lake is about 2,700 feet above sea-level, and, as determined barometrically, is a little less than forty feet *lower* than the nearest part of the Kootanie River, in the same valley. Its banks are formed by terraces, about one hundred feet in height, of the white silt deposits. The main valley has been blocked at the head of the lake by the delta formed by the Kootanie, and possibly also in part by that of Findlay Creek, on the opposite side. The lake is similarly held in at its lower end by the delta deposit of Dutch Creek. The trail follows the east side of the lake and runs part of the way along fine, grassy slopes, which lie between the lake and the base of the mountains. Copious springs issue in several places along this slope, and deposit considerable quantities of calcareous matter.

Hot spring.

Near the first stream from the east, beyond the lower end of the lake, and about two miles distant from it, is a copious hot spring. It is about half a mile east of the trail, on the slope of a hill, and issues in several places from the summit and sides of a rounded, calcareous knoll formed by its deposit. The main efflux, at the summit of the knoll, has produced a raised basin, which within measures about eight by four feet, and is two feet deep, forming an admirable natural bath. The discharge at this place is probably not less than twenty gallons per minute, and the temperature of the water at this (the hottest) point, was found to be 112° F. There is no discharge of gas, but the water has a slight styptic saline taste. The brook immediately south of, and opposite the spring, has formed a miniature cañon by cutting for a considerable distance, through calcareous tufa, which in superposed flaggy layers, forms a thick deposit, overlying the gravelly material of the higher terraces. Sir George Simpson, who visited this spring in 1841, gives the following notes respecting it.—

Sir George Simpson's remarks.

"Near our encampment, we observed that the stones in the bed of a little stream were covered with a yellow crust. Before starting for the day, Berland conducted us to three hot springs, about three miles distant, which doubtless caused the phenomenon in question. The

waters tasted slightly of alum, and appeared to contain a little magnesia; and, though we neglected to take our thermometer with us, yet, on returning to camp, we estimated the three temperatures respectively at about ninety, a hundred and a hundred and twenty degrees. Two winters back, Berland, while suffering from a severe illness, made a bathing-place of these springs; and he either actually was, or believed that he was, benefited by them."*

Lower Columbia Lake.

The Lower Columbia Lake is separated from the Upper by about seven miles of marshy valley, through which the river winds. Its general appearance is similar to that of the Upper Lake. The general direction of the valley, with its bordering ranges, here suffers a marked change in trend, turning more to the westward, in correspondence with the similar change in direction found on the east side of the range at the Highwood Gap, which is in the same latitude.

Columbia Valley.

From the lakes to the Kicking Horse River, the character of the valley is nearly everywhere the same. The depression in the centre of the valley, in which the Columbia flows, is a mile or more in width, and is occupied by a series of swamps and lagoons among which the river pursues a tortuous course, with a comparatively sluggish current. This axial depression is bordered on both sides by terraces, of variable width which become more densely and uniformly wooded northward, and are broken by the deep valleys of numerous small tributary streams. On the west side, the valley for the greater part of its length, spreads widely, the surface rising gradually but irregularly in terraces and low ridges toward the base of the Selkirk Mountains, Long Mountain and high, rocky ridges to the north of it, however, narrow the valley for a distance of about twenty-five miles, being interposed between the river and the Selkirk Mountains.

Bordering mountain ranges.

The limestone range, which borders the valley continuously on the east, is steep, rough and bare, but seldom includes mountains exceeding 8,000 feet in height, till it approaches the Kicking Horse. The streams joining the river from this side, though numerous, are small, and drain inconsiderable areas in the Stanford, Brisco and Beaver-foot ranges. The outer range of high mountains in the Selkirks is usually distant six or seven miles from the river, and its lower slopes are all densely wooded. This range is cut by a number of important valleys, which carry tributary rivers of considerable size to the Columbia. The forms of many of the mountain masses in the Selkirks are fine, and the height of some of them is considerably over 9,000 feet above the sea-level. These mountains are shown on the map, as approximately fixed by bearings and sketches from the east side of

* Narrative of an Overland Journey Round the World. Vol. I., p. 128.

the valley. Their delineation must, therefore, be accepted as approximate only, and no facts bearing on their geological structure were obtained.

Rocks found along Columbia Valley.

The limestone rocks of the mountains on the east side of the Columbia valley, though often much disturbed, show a general tendency to eastward or north-eastward dips, and along the border of the upper part of the Upper Columbia Lake, soft, grey, slaty argillites, with some layers of dolomitic limestone, appear at high angles, unconformably underlying the great limestone series. These rocks are referred to the Cambrian, but the few fragments of trilobites found in them cannot be determined even generically. Between the Columbia Lakes, some yellowish-weathering, coarse sandstones, with conglomeritic layers, charged with quartz pebbles, are also referred to this formation, but doubtfully. Thence, for many miles northward, the rocks of the limestone series appear in a number of places along the edge of the valley, and probably underlie its whole width. They seem also to form Long Mountain, the beds in which are nearly horizontal. Twenty-two miles south-east of the mouth of the Kicking Horse, Cambrian, slaty rocks, precisely resembling those above described, re-appear, and are seen in a number of places all the way to the Kicking Horse. They evidently form a narrow, continuous band, along the line of the Beaver-foot Range. Their uniformity in appearance is noteworthy, as also their exact resemblance to those immediately underlying the limestones on the Kicking Horse River, at several places between its mouth and the south-east end of Mount Hunter. On the slopes of the Beaver-foot Range, above these rocks, very massive beds of white or yellowish quartzite are associated with the limestone series, and these are provisionally included with the limestones under the blue colour on the map.

Glaciation and drift deposits.

The occurrence of large, loose blocks of this quartzite rock, many miles south of its outcrops, along the Columbia Valley, together with distinct glaciation in the same direction, seen on one or two surfaces of limestone, show, pretty clearly, that the ice which must have occupied the valley during the glacial period, moved southward. The white silts, found so extensively developed in the southern part of this great valley, also continue in this northern portion, but toward the mouth of the Kicking Horse, become gradually less characteristic in appearance, changing to a yellower shade of colour. They are also not so uniformly fine in texture, and are more than elsewhere mingled with gravelly intercalations. This change appears to afford additional evidence of the fact that thew hole valley, at the time of the formation of the terrace-deposits, drained to the south. Facts showing that its drainage followed the same direction during the formation of the still later axial trough, have already been cited (p. 31 B).

No fossils sufficiently well preserved to determine the age of the rocks, were collected by us in any part of the Columbia Valley, but Prof. A. P. Coleman of Victoria University, Cobourg, was so fortunate as to obtain a few fossils from the rocks of the south-west slope of the Beaver-foot Range, which he submitted to Mr. J. F. Whiteaves for determination. These included *Halysites catenulatus*, and *Favosites Gothlandicus*, with an *Orthis*, a *Rhynchonella*, and some crinoidal and cystidian columns, indicating a Silurian age. The first-mentioned species was collected in limestone which passed beneath quartzites probably identical with those above described. It is therefore probable that in this part of the mountains a considerable series of beds, intermediate in age between those of the Cambrian and Devonian, are developed, and the result of Mr. McConnell's work, on the Kicking Horse, will be awaited with interest in this connection. Fossils and age of rocks.

The auriferous character of several of the streams on the west side of the Columbia, in this part of its length, is referred to on a subsequent page.

Recapitulation of Geological Section.

Under this heading, it is intended to review, in brief terms, the features of the various members of the general section met with in this district of the Rocky Mountains, to compare the several local sections, and to note such other general facts as may be of importance.

Of the rocks referred to throughout this report as Cambrian, no complete general section can be offered. So far as this district is concerned, they form the basal formation, and it will probably be necessary to seek their actually lowest beds in the Purcell or Selkirk ranges, in which it is probable that they occur in conjunction with still older crystalline rocks. The component beds of the great Cambrian series are, in the main, quartzites and quartzitic shales, passing into argillites, and occasionally including limestone or more or less calcareous or dolomitic materials, and conglomerates. Sheets of contemporaneous trap also occur, probably at several horizons. The colours of these beds are extremely varied, and though, as a rule, considerably indurated, they seldom show traces of metamorphism resulting in the production of crystalline minerals. Cambrian.

The most instructive section obtained of a portion of the Cambrian formation, is that found near Waterton Lake, and in the eastern part of the South Kootanie Pass. This embraces a thickness of about 3,000 feet, and is detailed on p. 39 B. It is regarded as including a portion of the middle part of the formation as developed in this district, but somewhat careful search has failed to lead to the discovery of fossils in Sections near Waterton Lake.

it, and its constituent sub-series have not been clearly recognized in other parts of the region. This latter fact need not be supposed to indicate that the corresponding portion of the formation is elsewhere absent, but it is believed to arise from a variability in the composition of the series in different parts of the field. The rocks of the limestone series here rest with distinct unconformity on the eroded beds of the Cambrian.

Thickness.

Between the eastern summit of the South Kootanie Pass and the Flat-head River, the minimum estimated thickness of the outcropping Cambrian beds is 11,000 feet, but the section includes neither the summit nor the base of the series. Other sections show a probable thickness of over 5,000 feet for a part of the series, but none were found in which its whole volume could be ascertained.

Lithological character.

Throughout all this region of the Rocky Mountains, the general appearance and composition of the Cambrian is similar, but some points of difference may be observed as between its southern and northern portions, and it is believed that an upper part of the formation is extensively represented in the north-western half of the district, which is either entirely wanting or but seldom preserved in the south-eastern. The limestone, 200 feet in thickness, forming series B, in the sections near Waterton Lake, was not elsewhere recognized, and the massive, fine-grained, greenish and grey quartzites, referred to as the Elk River bridge beds (p. 78 B), found at several widely separated localities in the southern part of the district, were seen seldom, if at all, to the northward. To the south, also, the red beds, more fully mentioned later, are not nearly so characteristic or important. In the north-western part of the region, fine-grained argillaceous shales and slates, which become in some places glossy or silky in aspect from the incipient development of crystalline minerals, and vary in colour from black to pale grey or yellowish, are much more prominent, while the conglomerate beds, with quartz pebbles, are there also most frequently found. It is, further, in this north-western part of the district, that the few fossils which have been collected in this great quartzite or Cambrian series, were obtained. These occur within two or three thousand feet of the top of the formation as there developed, and, as already stated, represent a Middle Cambrian horizon, while no vestige of a fossil has yet been obtained from the rocks to the southward.

Conditions of deposit.

On the western part of the South Kootanie Pass, in connection with red beds, which include both sandstones or quartzites and shales, ripple-marked surfaces, surfaces broken by mud-cracks, and beds covered by pseudomorphs of salt-crystals, were observed; these evidencing not only shallow-water conditions, but showing that areas of sea-water, cut off from the ocean, had there become by evaporation

saturated solutions of sea-salt. Similar facts were noted near the lower part of the Elk River, and from their association with the red beds (an association repeated in the Triassic rocks of the same region) it may be safely assumed that the red coloration is connected in its origin with similar conditions. Such red beds are there extensively developed, and are believed to occur at two or more horizons in the series, and it is not improbable that the deposition of these presumably lower beds of the Cambrian, occurred in a basin, which was often, if not continuously, separated from the main ocean.

Pseudomorphs of salt crystals.

The pseudomorphous impressions of salt-crystals above referred to, are quite distinct in appearance, and easily distinguished from pseudomorphs of crystals of iron pyrites. They have been filled by clayey matter, while the rocks were still in a soft state, and have generally been much flattened by the subsequent consolidation of the material by pressure. It therefore appears necessary, to suppose that this part of the Cambrian was converted, not long after its deposition, into a land area, so as to allow the percolation through it of fresh surface waters. It is even possible that this occurred before the formation of the supposed later Cambrian rocks of the northern part of the region.

Conglomerates.

The conglomerates above alluded to were seen for the most part in connection with the Cambrian anticlinal of the upper portion of the Bow Valley. They are characterized by pebbles of milky or semi-transparent quartz, together with pieces similar in size of fresh-looking whitish felspar, and the matrix contains abundance of pale mica. These constituents have evidently been derived from some not far distant exposures of coarse granitic or gneissic rocks. Fragments are also found of dark, lustrous schist. Rocks of the character of those largely developed on Shuswap Lake and in the Gold Range would afford such material.*

Cambrian of Wasatch.

The Cambrian of this part of the Rocky Mountains resembles that of the Wasatch Mountains in Utah, in the fact that with the exception of the Middle Cambrian fossils near its summit, it is entirely destitute of traces of life. Its general lithological character is also similar. The Cambrian of the Wasatch is described by Messrs. Hague & Emmons as "a body of quartzites more or less argillaceous, having some fine-grained mica-schists in its upper portion, and, near the base of the part exposed, a bed of some 800 feet of dark-blue, almost black, finely laminated argillites. Its thickness, as estimated from the distances between outcrops and the average dip, cannot be less than 12,000 feet."†

* See Report of Progress, 1877-78, p. 96 B.

† Geological Exploration of the Fortieth Parallel, Vol. II., p. 366.

Cambrian of Grand Canyon.

The lithological resemblance is, however, in some important particulars, even closer as between the Cambrian rocks of this part of the mountains, and those of the Chuar and Grand Cañon groups of the Colorado Cañon in Arizona, as described by Mr. Walcott.* The occurrence of thick beds of parti-coloured shales, the abundance of ripple-marks and mud-cracks throughout, and especially the evidence (in the Grand Cañon group) of contemporaneous volcanic activity, in the form of interbedded greenstones, constitute points of identity with the series here described.

Absence of life.

In a paper received while this report is going through the press,† Mr. Walcott refers to the absence of the Lower Cambrian fauna in the western part of the continent, and provisionally refers it to a land barrier, supposed by him to have existed at that time between the eastern and western portions of the Continental . is perhaps worth noting the fact, that the body of wat.. hich) lower portion of the rocks here described were deposited, was a basin separated from the ocean, and, occasionally, if not continuously, in the condition of a saturated brine, may in itself explain the absence of life of any kind, at least in this particular region.

The facts at present available do not warrant any definite statement as to the character of the beds which appear to occupy a position between the Cambrian and the Devono-Carboniferous limestone series. It is evident that strata filling at least a part of this interval, occur in the north-western portion of the district here described, and their investigation is at present in progress by Mr. McConnell.

Limestone series.

The great limestone series of the mountains is referable, in a general way, to the Devonian and Carboniferous periods, and characteristic fossils have now been collected from many parts of it. Its thickness and development is probably irregular, and dependent on the contour of the older rock-surface on which it rests uncomformably Near the eastern end of the South Kootanie Pass, its volume was estimated at 1,000 feet (p. 39 B), while on the same pass, near Mount Yarrell, its minimum thickness is about 4,000 feet (p. 50 B). On the Crow Nest Lake there is an apparent thickness of 9,610 feet, but subsequent investigation renders it probable that this is due to folding, and that the actual exposed thickness is 3,575 feet, the base of the formation not being seen (p. 72 B). In this section and elsewhere, between 1,000 and 2,000 feet of the upper portion of the limestone is highly crinoidal in character.

A prolonged period of quiet marine deposition is indicated by this great body of limestone.

* American Journal of Science, Vol. XXVI., p. 437.
† Ibid, Vol. XXXII., p. 138.

Overlying, and blending with the highest beds of this limestone series is a thickness of several hundred feet of rather massive calcareous sandstones, which weather to reddish or yellowish tints. These were well seen near the Crow Nest Lake (p. 73 B). On the South Kootanie Pass, west of the Flat-head (p. 54 B), at the west entrance to the Gap of the North Fork of the Old Man (p. 80 B). Near the east end of the White Man's Pass (p. 113 B), on the Cascade River (p. 143 B) and elsewhere. In these beds, or in the limestones near this horizon, the greater part of the distinctly Carboniferous forms were found. On the Bow River, near the mouth of Red Earth Creek, and on the Elbow, forming the eastern edge of the isolated limestone area in the foot-hills (p. 104 B) a considerable thickness of black, flaggy, highly calcareous shales was observed occupying a similar position at the top of the limestone series, and possibly representing a local difference in character of sedimentation on the same horizon. Highest beds of limestone series.

South of the line of the Crow Nest Pass, the limestone series is conformably overlain by rocks which are referred to the Triassic or Permo-Triassic. In the vicinity of the South Kootanie Pass, an interbedded, amygdaloidal diabase everywhere occurs at the base of the Triassic rocks. This, though classified under a separate letter (E) in the general section of that region (p. 39 B), is now known from the occurrence of a similar bed (if not the extension of the same one) among the distinctively Triassic rocks of the summit of the North Kootanie Pass (p. 60 B) to be more properly ranked as a member of that series. The trap flow has a thickness of fifty to one hundred feet, and is overlain near the South Kootanie Pass by red beds and fawn-coloured magnesian sandstones, 600 feet in thickness. Near the North Kootanie summit it forms part of a similar series of alternating, flaggy, magnesian sandstones, and red sandstones and shales, 2,000 feet in thickness (p. 60 B). In connection with the red beds, ripple-marked surfaces, mud-cracks and impressions of salt-crystals occur, the whole indicating, as the conditions of deposition of the rocks, those of a basin cut off from the main ocean. Triassic.

With the single doubtful exception of certain red beds, seen from a distance, near the summit of the White Man's Pass (p. 115 B), these Triassic rocks are entirely confined to the district south of the Crow Nest Pass, and, as elsewhere more fully shown,* we find here probably the northern limit of a great Triassic mediterranean sea, which extended far to the southward in the western part of the present Continental area. Distribution.

* Trans. Royal Soc. Canada, Vol. I., Sect. IV., p. 143.

Precise age doubtful.

The entire absence of fossils makes it impossible to decide the age of these beds on palæontological grounds, but their stratigraphical position and similarity to the Triassic of regions to the south, render it nearly certain that they are, in part at least, properly referred to that formation. The gradual character of the passage from the upper beds of the limestone series (broken only by the casual intercalation of trap), tends to show that part of the lower portion of the series may not improbably represent the Permian period.

Cretaceous.

The rocks of the Cretaceous, are the next in ascending order known in this region. Over the area of the great plains, both in the United States and Canada, and in the Rocky Mountain region south of this district, the lowest rocks of the Cretaceous series developed, are those of the Dakota, of Middle Cretaceous age. In the vicinity of the West Coast, Lower Cretaceous rocks are found, and in this part of the mountains we appear to enter upon the edge of the area of deposit of the Lower Cretaceous, the beds here named the Kootanie series occupying

Kootanie series.

that horizon. The geological horizon of the Kootanie series is determined by its position relatively to the higher members of the Cretaceous series, and by the fossil plants which it has yielded, which

Fossils.

are enumerated on former pages. No fossil remains but those of plants have been found, with the exception of a broken fragment of a mollusc, which is pretty evidently a *Goniobasis*, from the plant beds of Coal Creek, and part of the guard of a belemnite from the beds of the Cascade basin. Though the Kootanie series is here throughout spoken of as a portion of the Cretaceous, its fossil flora shows, according to Sir J. W. Dawson, points of affinity with the Jurassic of some other regions. The plants "consist of ferns, cycads and conifers, some of them identical with, or closely related to, those of the Jurassic of the Amur country in Siberia, and others similarly related to the Lower Cretaceous of Greenland, as these floras have been described by Heer. This group, undoubtedly represents the flora of the Lowest Cretaceous, which has not hitherto been recognized in Western America."* The localities from which plants of this stage have already been collected, in the district here described, are comprised within an area about a hundred and forty miles in length by forty in breadth, but occur in several now distinct Cretaceous infolds. That the series characterized by these plants is a wide-spread and important one, is shown by the fact that one of the species (*Pinus Suskwaensis*) had previously been found on Suskwa River, in Northern British Columbia, at a distance of 580 miles north-west of the most northern locality here referred to.

* Trans. Royal Soc. Canada, Vol. III., Sect. IV.

Conditions of deposition of Triassic and Cretaceous.

The relation of the lowest beds of the Kootanie series, or base of the Cretaceous, to the Triassic beds of the southern part of the district, has not been observed, but northward, in a number of places, these rocks have been found to rest with an appearance of conformity on the calcareous sandstones, previously described as forming the summit of the limestone series. The occurrence of conglomerates in association with the Kootanie series, largely composed of rolled chert pebbles from the limestones, and containing, also, fragments of limestone, evidences, however, that the limestone series was fully hardened, and that segregative action had had time to produce its characteristic silicious concretions before the beds of Kootanie age were formed. We have already seen, that it is probable that the Triassic red beds never extended to the north of the southern part of this portion of the Rocky Mountains. If they did so, they must have been removed by denudation before the deposit of the first Cretaceous beds, and it is highly improbable that this should have occurred in such a way as to leave the calcareous sandstones above mentioned, so generally at the actual surface, at the moment when the deposition of the Cretaceous commenced. The denudation necessary for the removal of the Triassic beds, would probably have produced a rough, irregular, worn surface, on which the Kootanie beds would be found to rest. The fact being otherwise would appear to show, that deposition ceased in the northern part of the area during the Triassic, in consequence of the gentle upraising of this northern region to form a wide area of low, flat land, not likely to be affected by severe denudation. It is possible that this land was actually that which separated the enclosed Triassic mediterranean of the south, from the truly marine Triassic area of the *Monotis* beds, developed in the Peace River region and elsewhere to the north. At a later date flexure occurred, the waters again invaded the land area by hollows and depressions, in which the lowest beds of the Kootanie group were at once laid down; while intervening anticlinals stood out as rocky islands and more or less extensive land areas, the wearing away of which supplied the materials for the conglomerates and sandstones of the Kootanie and later Cretaceous beds.

Constitution of Cretaceous series.

No complete section can yet be given of the Cretaceous rocks of the mountain region, nor of those of the adjacent foot-hills, which, doubtless, at one time formed a continuous sheet with them; and on the accompanying map it has been deemed advisable to give one colour not only to the various sub-divisions of the Cretaceous, but also to such Laramie rocks as occur within the area. Two horizons appear, however, to be fixed with considerable definiteness in the lower part of the Cretaceous of the mountains,—that of the most important and persist-

ent coal-seams, and that of the volcanic intercalation. The first of is fixed in part, by the similarity of appearance and character of the coals and beds near them, but chiefly by the very similar group of fossil plants, which is found in association with these coal seams.

Coal-bearing horizon.

The coal-bearing horizon found in two places on the eastern part of the North Kootanie Pass (pp. 58 B., 59 B), at the western summit of the same pass (p. 64 B), on the Crow Nest Pass (p. 69 B), and at two places on the North-west Branch of the North Fork of the Old Man (pp. 87 B., 88 B), together with that of the chief coal seams of the Cascade trough, both on the Bow and Cascade Rivers, and on the Red Deer (pp. 126 B., 146 B), the coals of Fording River (p. 109 B), and probably of the Green Hills, near the Elk River (p. 110 B), is believed to be nearly, if not quite identical. In the adjacent foot-hills the coal met with near the mountains on the North Fork of the Old Man is probably also on the same geological plane.*

Thickness of Cretaceous series.

The thickness of rocks of the Kootanie series below this coal-bearing horizon was estimated on the Crow Nest Pass, and near the west summit of the North Kootanie Pass at about 7,000 feet, which may be taken as a minimum estimate of the greatest observed development of this part of the series. The beds are chiefly shales and sandstones of very varied texture and appearance.

The volcanic ash beds and agglomerates of the Cretaceous, in this region, are evidently due to a local eruption, which had its centre in the latitude of the Crow Nest Pass. These volcanic rocks have, however, been traced north and south from this point over a total length of forty-five miles, and may probably have at one time had as great an extension east-and-west, though this has subsequently been dimished by the folding together of the beds. The volume of strata between the coal-bearing horizon and base of the volcanic rocks on the Crow Nest Pass, was estimated approximately at 3,350 feet, on the South Kootanie Pass at 2,400. The mean of these approximations, 2,750 feet, may for the present be adopted as a probable result. The volcanic rocks themselves, on the Crow Nest Pass, where they attain their maximum, have a volume of about 2,200 feet, but thin out very rapidly to the north and south.

Summit of Kootanie group.

The summit of the Kootanie series is not yet precisely defined, but is situated betweeen the apparently-constant coal-bearing horizon and the base of the volcanic beds, as, on the North-west Branch of the North Fork (p. 88 B), fossil plants, believed to represent the horizon of the Dakota, are found a few hundred feet below these volcanic beds. This observation would make the horizon of the volcanic rocks them-

* See Report of Progress, 1883-84, p. 103 C.

selves as nearly as possible identical with that of those previously referred to (p. 69 B), as having been noted by Prof. Stevenson in Colorado. It is, therefore, not improbable that we find in these two very widely separated localities, traces of an epoch of volcanic activity in the Dakota period, which may yet prove to be important. Volcanic rocks are also largely developed in connection with the lower parts of the Cretaceous on the west coast of British Columbia.

Rocks of Kootanie series

The sections representing the upper part of the Cretaceous rocks of the mountains are, unfortunately, very unsatisfactory, the best being that of the North-west Branch just alluded to (p. 88 B). The volcanic beds are there followed by dark shales which afford a few fossils referred to the Benton group, and are estimated to attain a minimum thickness of 1,400 feet. Above these are sandstones and shales, generally of pale tints and possibly several hundred or a thousand feet in thickness, which are supposed to represent the Belly River series of the plains to the eastward. A concealed area beyond these, is presumed to be underlain by the Pierre shales, and still higher in the section are beds referable to the base of the Laramie, with characteristic fossils. The thickness of the Laramie at this place is indeterminate, but must be considerable.

Rocks of Cascade trough.

The section of the Cretaceous rocks of the Cascade trough, to the north, has not been referred to in the preceding paragraphs. Its distance from the localities here particularly described, and the entire absence of the volcanic intercalation, renders precise correlation at present impossible. The plants found in association with the principal coal horizon are, however, similar to those elsewhere observed in the same connection, and, as previous stated, it is not impossible that the thicker coal-seams occupy a similar horizon throughout. The chief al-seams here hold a middle position in a section showing at least 0 feet of sandstones and shaly beds, and including numerous less important coal-seams. At 2,500 to 3,000 feet above the thickest coal-seams, are important beds of conglomerate, which are possibly on the same horizon as those of the summit beyond Marten Brook on the west part of the Crow Nest Pass, which were estimated to be at least 1,500 feet above the coals of Marten Brook. On the hypothesis that the principal coal-bearing horizon of the Cascade basin occupies the same position as that developed in the southern part of the district, the thickness of beds found above this plane in the Cascade basin, would appear to indicate that the upper members of the section there, may be referable to the Dakota group. None of the characteristic plants of that group have, however, so far been obtained from these rocks.

A provincial general representation of the Cretaceous beds of the

General section of Cretaceous.

mountains of this region, as compared with those of the plains to the east,* may be given as follows, in descending order:—

		Rocky Mountains.		*Foot-hills and Plains.*	
			FEET.		FEET.
Laramie.		St. Mary River beds (base)	[not known].	Porcupine Hill beds	2,560
				Willow Creek beds	450
Cretaceous.				St. Mary River beds	2,800
		Fox Hill and Pierre	["]	Fox Hill and Pierre	830
		Belly River series	["].	Belly River series	910
		Benton and (Niobrara ?)	1,400	"Lower Dark Shales"	800
		Volcanic rocks (greatest thickness).	2,200		
		Dakota and upper part of Kootanie series to coal-bearing horizon	2,750		
		Lower part of Kootanie series	7,000		
			13,350		8,290

Total volume.

Adding the estimated volumes of the series of the adjacent plains, down to and including the Belly River series, to those of the lower groups of the mountain area, we arrive, for the Cretaceous of the region, at a total maximum thickness of 20,840 feet. While there is yet no certainty that the whole of this vast series of beds was deposited in any one part of the region, no evidence of a contrary tendency is known, and so far as observation goes, the beds of the plains show a decided increase in thickness on their approach to the foot-hill and mountain area.

Circumstances of deposition.

With regard to the circumstances of deposition, in the area of the mountains here particularly described, the following statement may be made. Marine conditions appear in connection with parts of the Kootanie group, but it is evident, that while a great subsidence was in progress, sedimentation in general more than kept pace with it, leading to the frequent occurrence of tracts of land on which vegetation could flourish. This continued to be the case till the volcanic eruption which produced the ash and agglomerate beds occurred, and it is even probable, from the discovery of plant remains in them, (p. 57 B) that some of these beds were sub-aerial. The sea held a prolonged sway over the region during the deposition of the Benton shales with marine fossils, but it is not known whether fresh-water and terrestrial conditions supervened in this particular district during the prevalence of such conditions over the neighboring area of the plains in the Belly River period. The Pierre shales having been found in the adjacent foot-hills to hold marine fossils tends to show, that at the time of their depositions, marine conditions must have prevailed also over the area of the mountains. As in the adjacent foot-hills, the base of the Laramie consists of estuarine deposits.

* See Report of Progress, 1882-84, p. 112 C.

Of the character of the Miocene (?) beds, referred to in the descriptive portion of the report (p. 52 B), so little is known that nothing need be said of them here, except to note, that their area is apparently not extensive, and that they represent the first known renewal of sedimentation after the great period of mountain making, and a vast erosion, which left the surface much in the condition in which it now appears. They lie in one or more valleys and are probably the deposits of ancient fresh-water lakes, like those found in Miocene times in the Interior Plateau region of British Columbia. Miocene.

A number of facts connected with the glaciation of this part of the mountains, have been noted on previous pages of this report. The general features indicated by them add little to the sketch of the glacial phenomena for this region, given in a previous report.* All the valleys in the mountain area have evidently at one time been choked with ice to a great depth, and glaciers debouched from them into the foot-hill region to the eastward, while a great combined glacier with southward movement, seems to have filled the Columbia-Kootanie Valley on the west. Notwithstanding this, there appears to have been very little heavy ice action or transport of material in some portions of the range, as in the region above the head waters of the Old Man River. Glaciation.

It is also worth noting, that while boulders of eastern Laurentian rocks are found up to the very base of the range near the forty-ninth parallel (as described in the report just referred to), no fragment of rocks of this kind has been found in any part of the mountains proper.

One other point, which appears to be anomalous, and which I will at present not venture to endeavour to explain, is the occurrence of heavy glacial striation in a southward or south-eastward direction, on surfaces on the bank of the Jumping Pound River, about thirteen rock miles east of the base of the mountains, in a region of wide valleys and low foot-hills.

General Note on Economic Minerals.

The occurrence of the various minerals of economic value, has been fully described in connection with the localities in which they are found. It will, therefore, be necessary, in conclusion, merely to recapitulate the main facts. Distribution of Coals.

The Cretaceous rocks, coloured green on the map, are the coal-bearing series of the region, and coals have already been found in a number of places in each of the great basins represented. These basins, or troughs, are distinguished by name as the Crow Nest, Elk River,

* See Report of Progress, 1882-84, p. 139 C.

and Cascade River troughs respectively, for convenience of reference. Owing to the rough character of the country and the complication of the outcrops, it is certain that but few of the actual exposures of coal have yet been discovered, and that the number and extent of the seams as now known will be largely increased by future research. The adjacent foot-hills are also well supplied with excellent coals, as more fully described in the Report of Progress for 1882-84. Within the mountain area, many of the coal outcrops are in localities so remote and difficult of access, that their possible utility is considerably lessened. Others can be reached and used without much difficulty when required, and the anthracite of the Cascade basin is already being opened up. It is also probable that the discovery of metalliferous ores in various parts of the mountain region, will at a future date, cause the coals of places otherwise unimportant to be drawn upon for smelting purposes.

Reference to map.

The principal known coal outcrops are numbered consecutively on the face of the accompanying general map, and references given to the pages on which they are described.

Character of coals.

Within the mountain area, the coals so far examined occur chiefly in the Kootanie group, or lowest Cretaceous, and, with the single exception of those of the Cascade basin, they rank as bituminous coals. The anthracitic character of the coals of the Cascade basin does not even extend to the whole area of this Cretaceous infold, but is evidently due to exceptionally severe local alteration, as, on following the same beds northward to the Red Deer River, the contained fuels became coaking coals. Loose fragments of coal found in the upper part of Sheep Creek, in the northern extremity of the Crow Nest trough, show a tendency to become anthracite, but the beds were not found in place. The fuel most nearly approaching a lignite is that derived from the beds in Oyster Creek, which contains four per cent. of hygroscopic water.

Gold.

The only part of the region which has obtained a recognized position as a gold-mining district, is Wild Horse Creek, described on p. 152 B, but nearly all the streams flowing into the Columbia-Kootanie Valley, are known to contain more or less alluvial gold, and on some of these, particularly those joining from the west, paying claims have been worked. The restricted character of the portion of Wild Horse Creek which has proved so richly auriferous, shows how easily similarly rich portions of other creeks may be passed over in this rough, mountainous country, and should be an incentive to the prospector to carefully examine all portions of the district which are based on the slaty zones of the Cambrian. No auriferous alluvial deposits have yet been found to the east of the watershed in the mountain region, and though the gravel bars of

numerous streams were examined by washing, not even 'colours' could be obtained on this slope. It is still possible, however, that paying placers will be found within some of the Cambrian areas there, and as worthy of examination, I may note, the Cambrian anticlinal of the upper Bow Valley, and its south-eastward continuation on the branches of Red Earth Creek.

Copper and lead

Copper and lead ores occur in this part of the mountains in considerable abundance. Most of those which have been prospected are in the vicinity of the Bow and Kicking Horse rivers and near the Columbia-Kootanie Valley. It is probable that some of these deposits already known, will prove to be of a remunerative character, and that many others will be discovered. It should, however, be stated that so far as the analyses of these ores yet made can be accepted as an indication of their general composition, the quantity of gold or silver carried by them is inconsiderable. The connection of deposits of this character with certain igneous intrusive masses has already been referred to (p. 123 B). It may reasonably be expected that metalliferous veins will also be discovered within the area of the Cretaceous rocks of the foot-hills or those portions of the same rocks which occur in the mountains, where the strata are found locally to be considerably altered, the sandstones being in some cases converted into true quartzites. Should such deposits be found in connection with these rocks, they may prove to be quite different in character from those of the limestone and Cambrian series.

Building stones, lime, etc.

Stones suitable for building purposes, are present in great abundance in almost all parts of the mountains. Limestone well adapted for burning is also everywhere to be found, and outcrops along the line of railway between Canmore and Kananaskis stations may be utilized with advantage for the supply of Calgary and other points to the eastward. Though slaty rocks are abundant in the Cambrian, none were seen which in regularity of cleavage, and other characters, are suitable for building purposes, and, in any case, such deposits could be worked only near the line of railway. The marble of the upper part of the Cross River (p. 116 B) is of no economic importance, owing to the inaccessible character of that part of the region. The sodalite of the Ice River is adapted for use as an ornamental stone, and might be worked up into very pretty jewelry.